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JOURNAL OF PALEONTOLOGY

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VOLUME 18 MARCH, 1944 NUMBER 2

FOSSIL CORALS OF THE GENUS TURBINOLIA FROM THE GULF COAST

EDWARD MONSOUR

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ABSTRACT—The stratigraphic distribution of species of *Turbinolia* in the Gulf Coast Tertiary beds was determined by the study of a large number of specimens from 84 localities in Texas, Louisiana, Mississippi, and Alabama. This study reveals that the fossil genus ranges in age from basal Midway (Clayton) to upper Vicksburg (Byram). The genus is most common in the Claiborne, less common in the Jackson, and rare in the Midway, Wilcox, and Vicksburg groups. Five new species and three varieties are described, and the range, distribution, evolutionary trends, and ecology of *Turbinolias* are discussed.

INTRODUCTION

THE genus *Turbinolia* has a wide distribution in Tertiary deposits of the North Atlantic and northeastern Pacific basins. Specimens have been reported and described from Europe, Africa,[1] South America, and North America. The only noted occurrence of the genus in modern seas was reported by Pourtalès (1879) from off the coast of Cuba.

The stratigraphic range and distribution of the genus have received little attention from paleontologists in the Gulf Coast region of the United States. The only previous studies of *Turbinolia* in this region were made by Isaac Lea (1833) and T. Wayland Vaughan (1900). Lea described *T. pharetra* from the Claiborne at Claiborne, Alabama, while Vaughan described *T. wautubbeensis* from the lower Claiborne, *T. claibornensis* from the Claiborne sand, and *T. insignifica* from the lower Oligocene, Red Bluff beds.

The writer collected many specimens of this delicate, minute coral while doing field work along the outcrop of the Claiborne and Jackson formations in Texas and Louisiana. Preliminary investigations of these specimens indicated that certain forms of *Turbinolia* were sufficiently diagnostic to warrant more extensive study. The collections of the School of Geology Museum, Louisiana State University, and the private collection of Dr. H. V. Howe, Director of the School of Geology, were examined. Field trips were made to type localities of the Tertiary in Mississippi and Alabama and many additional specimens of the genus were collected from different parts of the section. Altogether, coral specimens from 84 localities, distributed from central Texas to Alabama, were examined.

DISCUSSION

The writer was able to distinguish five new species and three varieties of the genus

[1] Two specimens reported but not described from the upper Eocene of southern Nigeria, mentioned by Newton (Nigeria Geol. Survey, Bull. 3, p. 8, 1922), are in the British Museum (see Wells, 1937).

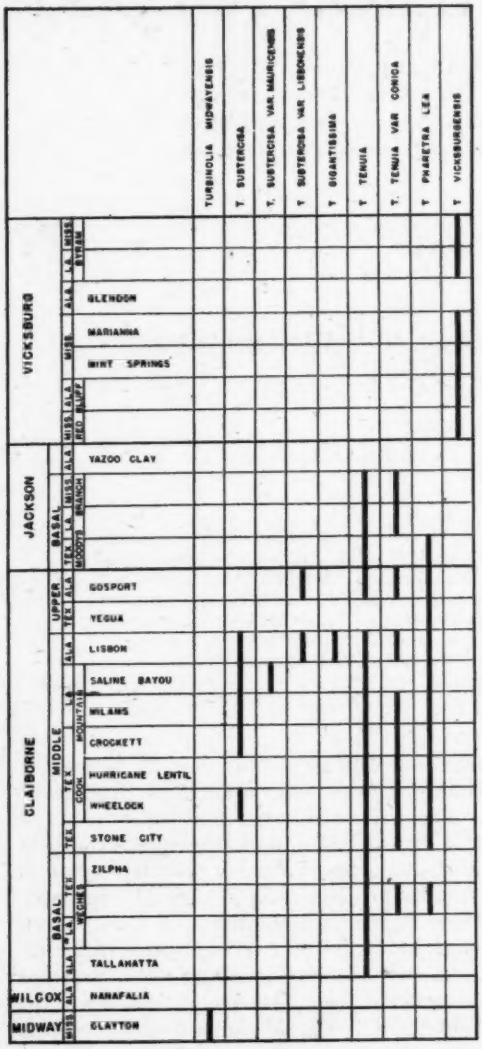

FIG. 1—Stratigraphic distribution of Gulf Coast species of *Turbinolia*.

T. wautubbeensis and *T. claibornensis* from the Claiborne and *T. insignifica* from the Red Bluff, species described by Vaughan (1900), were not found.

* Weches on Louisiana side Sabine River (See Loc. 4.)

Turbinolia. One of these, *Turbinolia midwayensis*, is the first to be recorded from Paleocene deposits and therefore extends the range of the genus.

Check list.—The ranges of all species reported from the Gulf Coast sediments and found by the writer are included on the stratigraphic check list, fig. 1. This check list also indicates that unidentifiable casts of *Turbinolia* were found in the basal Wilcox, Nanafalia formation; the middle Jackson, Yazoo Clay; and the middle Vicksburg, Glendon formation. A notation on the chart indicates that several previously described species were not recognized in the collections studied.

Index species.—Several of the species have a sufficiently widespread distribution and sufficiently narrow stratigraphic range to be of use in correlating units of the Gulf Coast Tertiary sediments. *Turbinolia subtercisa*, which characterizes the middle Claiborne beds of Eocene age, is an excellent diagnostic fossil. Other fossils with narrower stratigraphic range but with a limited geographic distribution are also of value in correlative work. Typical of these are *T. subtercisa* var. *mauricensis* of the upper Cook Mountain of Louisiana, *T. subtercisa* var. *lisbonensis* of the Lisbon and Gosport of Alabama, and *T. gigantissima* of the Lisbon of Alabama.

Evolutionary trends.—The basic aspects of evolution in the genus *Turbinolia* were presented by Quayle (1932) who divided the species into two main groups, one characterized by a styliform columella, the other by a stellate columella. During Eocene time, the latter flourished in America and the former in Europe; during the Oligocene the styliform group appeared in America.

The present study has revealed the additional information that the styliform group represented by *T. midwayensis* reached America in the Paleocene.

The two main stocks of the genus have definite ranges in the Gulf Coast Tertiary. The styliform group is found in the Paleocene and again in the Oligocene sediments. The stellate group is found only in the middle and upper Eocene, the Claiborne and Jackson groups.

It is possible, as suggested by Quayle, that the stellate stock in the Gulf Coast may have been derived from the hexagonal styliform type characterized by *T. acusticostata* Vaughan, an Atlantic Coast Wilcox form not examined by the writer but no supporting evidence for this conclusion occurs in the Gulf Coast deposits. Until more

factual data are obtained it must be considered that, after its appearance, the stellate group rapidly became extinct, and that the styliform group shifted and periodically disappeared from the Gulf Coast region.

Ecology.—*Turbinolia* occurs only in marine beds of glauconitic sands, glauconitic clays, or in calcareous clays which carry warm water faunas. Its presence in the Tertiary sections is limited to near-shore or beach facies such as the lower Claiborne, Weches formation; the basal Cook Mountain beds; the upper Claiborne, Gosport sands; and the basal Jackson, Moodys Branch marl, or to slightly deeper water marine clays which overlie these units. No *Turbinolia* has been reported from the shallow-water carbonaceous clays which carry a brackish water fauna. It is concluded, therefore, that the genus lived in comparatively shallow, warm water seas of normal salinity.

The occurrence of the only known living species collected off the Coast of Havana, Cuba, at a depth between 220 and 310 fathoms indicates a deeper water habitat than do the occurrences of the fossil species. However, Wells (1937) indicates that the species described by Pourtalès (1879) is a subgenus, *Turbinolia* (*Batotrachus*) *corbicula*, and therefore its habitat may have little value in indicating Tertiary environments.

CONCLUSION

The genus *Turbinolia* has definite value for correlations of the Gulf Coast Tertiary sediments. The two main stocks can be used for correlation of larger groups and several of the species can be used as index fossils for minor sedimentary divisions.

LOCALITY LIST

MIDWAY GROUP

Clayton formation

1. Mississippi. Upper "marl" member at Chalybeate Springs, about 2½ miles southeast of Walnut in sec. 3, T. 2 S., R. 4 E.; blue sandy somewhat fossiliferous marl. J. O. Barry collector. (Loc. 1273.)[2]

WILCOX GROUP

Nanafalia formation

2. Alabama. Barney's Upper Landing on the Tombigbee River. (Loc. 479.)

CLAIBORNE GROUP

Basal Claiborne

Tallahatta formation

3. Alabama. Little Stave Creek; above falls, 10–12 ft. below top of Tallahatta in *Lucina* clays and 8–10 ft. above *Discocyclina advena* zone. R. H. Smith collector. (Loc. 1613.)

Weches formation

4. Louisiana. About 1½ miles below Sabinetown, Texas on the Louisiana side of the Sabine River where Low's Creek flows into the river from the Texas side; there are some shoals at this locality. (Loc. 906.)
5. Texas. Four miles northwest of intersection west of town of Chireno, San Augustine Co.; 0–5 ft. below *Pecten* bed in road cut on south side of Texas State Hy. 21. (Loc. 1369.)
6. Just above Low's Creek on Texas side in Sabine County; bed of very fossiliferous greensand marl immediately above water level. J. B. Garrett collector.
7. Highway cut on Texas State Hy. 7 at Swift, about four miles west of Martinsville. (Loc. 1093.)
8. Thin clay seam 10 ft. above top iron-stone ledge at Smithville, Bastrop Co.
9. Smithville, Bastrop Co. (Loc. 1037.)

Zilpha member

10. Texas. Basal Zilpha at Smithville; glauconite bed.

Middle Claiborne

Stone City formation

11. Texas. Type Stone City at Stone City P. O., Burleson Co.; southeast bank of Brazos River, near Texas State Hy. 21 bridge. R. H. Smith and L. J. Wilbert collectors. (Loc. 933.)
12. Same as loc. 11, but 200 yards upstream from bridge. (Loc. 1275.)
13. Same as loc. 11, but downstream and stratigraphically overlying loc. 12. (Loc. 1275.)
14. Same as loc. 11, but downstream and stratigraphically overlying loc. 13; lower portion of bed characterized by numerous corals of the genus *Balanophyllia*. (Loc. 1278.)
15. Topmost Stone City; same as loc. 11, but downstream and stratigraphically overlying loc. 14; upper portion of bed characterized by an exceedingly large number of the gastropod *Conus*. (Loc. 1279.)
16. Topmost Stone City at Smithville, Bastrop Co.; 200 yards east of iron bridge over the Colorado River, 3 ft. above the bentonite bed. (Loc. 1230.)

Wheelock member

17. Texas. Basal Wheelock at Stone City P. O., Burleson Co.; along Brazos River, nearly beneath bridge of Texas State Hy. 21. (Loc. 1280.)
18. Same as loc. 17, but upstream from bridge and stratigraphically overlying loc. 17. (Loc. 1281.)

[2] Locality numbers following written localities are those of the Louisiana State University Geology Museum.

19. Same as loc. 18, but stratigraphically higher. (Loc. 1282.)
20. Smithville, Bastrop Co.; 200 yards east of bridge over the Colorado River, immediately above the bentonite bed. (Loc. 1231.)
21. Same as loc. 20, but stratigraphically above. (Loc. 1232.)
22. Brazos Co.; 200 yards north of bridge over Little Brazos River on Texas State Hy. 21. (Loc. 1235.)
23. Same as loc. 22, but overlying it, separated by one foot of section. (Loc. 1236.)
24. Same as loc. 22, but overlying loc. 23. (Loc 1238.)
25. Stone City, Burleson Co.; one-quarter mile downstream from bridge of Texas State Hy. 21 over the Brazos River, at junction of the river with its first tributary below the bridge; stratigraphically above loc. 19. (Loc. 1283.)

Hurricane lentil of the lower Landrum member (Stenzel, 1940)

26. Texas. Two Mile Creek, Leon Co.; exposure along creek banks beginning under iron bridge of Leona-Two Mile School country road, four miles south of Leona and extending upcreek some distance; bed (i). (Loc. 1224.)
27. Same as loc. 26, but farther up the creek and stratigraphically above; bed (p). (Loc. 1225.)
28. Same as loc. 26, but farther up the creek and stratigraphically above loc. 30; between beds (p) and (q). (Loc. 1226.)
29. Same as loc. 26, but farther up the creek and stratigraphically above loc. 31; immediately overlying the upper bentonite; bed (z). (Loc. 1227.)
30. Same as loc. 26, but considerably farther up the creek and higher stratigraphically than loc. 32. (Loc. 1228.)
31. Same as loc. 26, but considerably farther up the creek; topmost fossiliferous bed in the section, immediately below Stenzel's "Spiller sand."

Crockett member

32. Texas. Basal Crockett at bluff on Colorado River one-quarter mile east of bridge at Smithville. (Loc. 720.)
33. 9.4 miles south of Bryan on Texas Hy. 21 and on the right bank of Little Brazos River 200 yards north of bridge. (Loc. 108.)
34. Moseley's ferry on the Brazos River. (Loc. 1036.)
35. Same as loc. 34, but 40 feet below top of bluff, H. V. Howe collector.
36. Same as loc. 34, but 34 feet below top of bluff.
37. Same as loc. 34, but 20 feet below top of bluff.
38. Same as loc. 34, but 12 feet below top of bluff.
39. Upper Crockett at Pinoak Creek, one mile above Bastrop-Fayette Co. line; below 6–9 inch limestone ledge which separates the upper and lower.
40. Same as loc. 39; above limestone ledge.

Milams member

41. Louisiana. Road cut three miles northwest of Quitman; W ½ sec. 27, T. 16 N., R. 4 W.
42. Quitman, Jackson Parish.
43. Jackson Parish, near center of sec. 27, T. 16 N., R. 4 W. (Loc. 1097.)
44. Near middle of line between the NE ¼ and NW ¼ sec. 15, T. 16 N., R. 4 W. Gullies in the steep slope north of state road 1312, opposite farmhouse of J. M. Turner; 8 feet above base of exposed section. R. D. Russell and J. L. Martin collectors.
45. Same as loc. 44, but 15 feet above base of exposed section.
46. Same as loc. 44, but 16–17 feet above base of exposed section.
47. Same as loc. 44, but 22–24 feet above base of exposed section.
48. Same as loc. 44, but 25–26 feet above base of exposed section.
49. Winn Parish, SE ¼ NE ¼ sec. 22, T. 10 N., R. 5 W.; calcareous fossiliferous clay containing lenses and stringers of glauconite.
50. Winn Parish, east side State Hy. 5, just north of Dodson, 0.1 mile north of south line of sec. 22, T. 13 N., R. 3 W.; calcareous, glauconitic, fossiliferous clay.
51. Two miles southeast of Minden; SE cor. SE ¼ sec. 26, T. 19 N., R. 4 W. (Loc. 58.)
52. Same as loc. 51, but 50 yards south of U. S. Hy. 80; borehole sample.
53. Same as loc. 51, but few feet lower.
54. Road cut north side of Louisiana Hy. 545 in Jackson Parish; sec. 27, T. 16 N., R. 4 W. Fossiliferous zone just above iron stone ledge 6 feet above the Dodson member, a yellow-brown sandy marl.

Saline Bayou member

55. Louisiana. Type Saline Bayou at St. Maurice, Winn Parish. (Loc. 174.)
56. Type Saline Bayou; third iron zone under the bridge at St. Mauriec.

Lisbon formation

57. Alabama. Little Stave Creek; top oyster bed, collected from 2–6 feet below indurated ledge. R. H. Smith collector.
58. Little Stave Creek; 6 feet above base of Lisbon. (Loc. 1304.)
59. Little Stave Creek. (Loc. 1331.)
60. Little Stave Creek; station 059. (Loc. 1312.)
61. Claiborne, Alabama; under bridge at water level, lowest exposed bed of highly fossiliferous green shale. (Eugene A. Smith's bed 19.) H. V. Howe collector.

Upper Claiborne

Yegua formation

62. Texas. Type Yegua at Orell's Crossing, Elm Creek, 5.2 miles northwest of Giddings, Lee Co.; brownish gray, soft, finely stratified and ferruginous clays with a little dark blue shale and light blue sands. A. D. Ellis collector.

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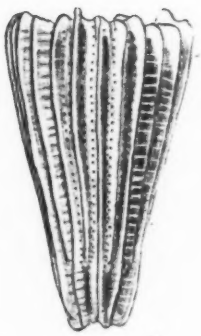
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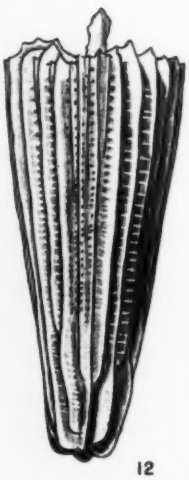
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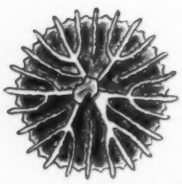
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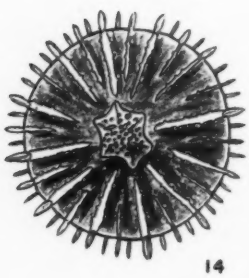
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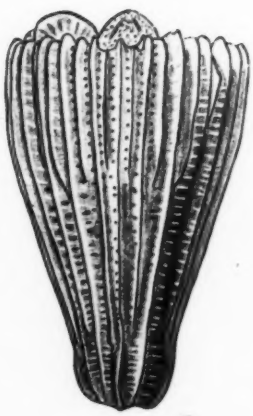
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Monsour, Tertiary Corals

UNIV. OF MICH.

Gosport formation

63. Alabama. Lower Gosport at Little Stave Creek, about four miles north of Jackson; very fossiliferous, brown ferruginous sand, underlies *Venericardia alticostata* bed. R. H. Smith coll. (Loc. 1148.)
64. Middle Gosport at Little Stave Creek; glauconitic facies overlying bed with abundant large *Venericardias*, 12–15 feet below *Scutella* bed. (Loc. 1299.)
65. Upper Gosport at Little Stave Creek; dark green, glauconitic marly shell concentrate 5 feet below *Scutella* bed and *Nonionella cockfieldensis*. (Loc. 1317.)
66. Claiborne Bluff at Claiborne, Ala.; 100 yards upstream from highway bridge. (Loc. 56.)
67. Claiborne Bluff; one-half mile below highway bridge.
68. Lowest fossiliferous bed exposed on Willow Branch in road cut on old road from Fail to Silas.

JACKSON GROUP

Basal Jackson

Moodys Branch marl

69. Louisiana. *Camerina* zone, one mile below Robinson's Ferry on the Sabine River. (Loc. 1200.)
70. Bluff of Red River at Montgomery. (Loc. 300.)
71. Texas—3.4 miles east of Pineland, Sabine County; one-quarter of a mile north of C.C.C. road on banks of Rock Creek.
72. San Augustine County.
73. Mississippi. Moody's Creek just south of Belhaven College, Jackson. (Loc. 681.)

Yazoo clay

74. Alabama. Gully 1½ miles north of Jackson; bed 5, 30 feet below top. H. V. Howe coll.

VICKSBURG GROUP

Red Bluff

75. Mississippi. *Corbula* bed at Hiwannee. (Loc. 690.) H. V. Howe coll.
76. Alabama. One-quarter of a mile east of Melvin.

Mint Springs marl

77. Mississippi. Falls nearest Mississippi River in Glass Bayou (adjoining National Park Cemetery) at Vicksburg; 3–10 feet below 25-foot limestone bed, 7 feet bluish-gray sandy clay. K. E. Young collector.
78. Same as loc. 77, but immediately underlying; from 0.7-foot shell bed in clay.

Marianna formation

79. Mississippi. Basal Marianna at Horton's Mill on the Chickasawhay River. (Loc. 1021.) H. V. Howe coll.

Glendon limestone

80. Alabama. Five feet above base at Glendon. (Loc. 1413.)

Byram marl

81. Louisiana. Shell Branch, 2½ miles south of Rosefield. (Loc. 155.)
82. *Coquina* bed from below highway bridge over abandoned railway at Rosefield. H. V. Howe coll.
83. Mississippi. Bluff one-half mile south of Mint Springs Bayou at Vicksburg. (Loc. 1.)
84. Top of falls in Mint Springs Bayou at Vicksburg.

KEY TO GULF COAST SPECIES OF TURBINOLIA

I. Columella styliform—
  A. Supernumerary costae absent..... ..... *T. midwayensis*
  B. Supernumerary costae present—
    1. Septa 20..... *T. insignifica*
    2. Septa 24—
      a. Costae not expanded basally..... ..... *T. vicksburgensis*
      b. Costae slightly expanded basally—
        a. Costae not crenulated..... ..... *T. claibornensis*
        b. Costae crenulated. *T. acuticostata*

II. Columella stellate—
  A. Supernumerary costae absent—
    1. Costae not expanded basally—
      a. Costae simple..... *T. tenuis*

PLATE 21

Magnification ×6½

FIGS. *1—Turbinolia subtercisa mauricensis* Monsour, n. sp., n. var. from locality 55, Saline Bayou member of the Cook Mountain formation. (p. 116)
2, 3—Turbinolia subtercisa Monsour, n. sp. from locality 20, Wheelock member of the Cook Mountain formation. (p. 116)
4, 5—Turbinolia midwayensis Monsour, n. sp. from locality 1. Clayton formation. (p. 114)
6—Turbinolia subtercisa lisbonensis Monsour, n. var. from locality 58, Lisbon formation. (p. 116)
7, 8—Turbinolia tenuis Monsour, n. sp. from locality 58, Lisbon formation. (p. 114)
9, 10—Turbinolia pharetra Lea from locality 12, Stone City formation. (p. 115)
11—Turbinolia tenuis conica Monsour, n. var. from locality 15, Stone City formation. (p. 115)
12, 13—Turbinolia vicksburgensis Monsour, n. sp. from locality 77, Mint Springs Marl. (p. 118)
14, 15—Turbinolia gigantissima Monsour, n. sp. from locality 58, Lisbon formation. (p. 116)

a. Corallum elongate..*T. tenuis* s.s.
b. Corallum conical.....
.....*T. tenuis conica*
b. Costae fluted.....*T. subtercisa*
a. Corallum elongate, intercostal furrows narrow.....
.....*T. subtercisa* s.s.
b. Intercostal furrows broad—
a′ Corallum conical.....
.*T. subtercisa mauricensis*
b′ Corallum elongate.....
..*T. subtercisa lisbonensis*
2. Costae expanded basally...*T. pharetra*
B. Supernumerary costae present—
1. Costae not expanded basally.....
.....*T. gigantissima*
2. Costae expanded basally.....
.....*T. wautubeensis*

SYSTEMATIC DESCRIPTIONS

Phylum COELENTERATA

Class ANTHOZOA

Subclass HEXACORALLA Haeckel

Milne Edwards and Haime

Family TURBINOLIIDAE Milne Edwards and Haime

Subfamily TURBINOLIINAE Milne-Edwards and Haime

Genus TURBINOLIA Lamarck, 1816

Turbinolia (in part), Lamarck, 1816, Hist. nat. Anim. s. Vert., vol. 2, p. 229.
Turbinolia (in part), Ehrenberg, 1834, Corall. roth. Meer, p. 53.
Turbinolia (in part), Dana, 1848, U. S. Expl. Exped., Zooph., p. 374.
Turbinolia, Milne-Edwards and Haime, 1848, Ann. Sci. nat., (3), vol. 9, p. 235.
Turbinolia, Milne-Edwards and Haime, 1850, Mon. Brit. Foss. Cor., p. xvi.
Turbinolia, Milne-Edwards and Haime, 1857, Hist. nat. Corall., vol. 2, p. 60.
Turbinolia, de Fromentel, 1860, Introd. Ét. Pol. foss., p. 91.
Turbinolia, Duncan, 1885, Jour. Linn. Soc. London, Zool., vol. 18, p. 18.
Turbinolia, Quayle, 1932, San Diego Soc. Nat. History, Trans., vol. 7, p. 94.

Corallum simple, conical, straight, and presenting no trace of adherence. *Calice* circular. *Columella* styliform. *Septa* exsert, those of the last cyclum bend toward the neighboring ones and united to them. *Costae* lamellar, straight, entire, and very projecting; the intercostal grooves presenting a double series of small dimples, resembling pores.

Type species, *Turbinolia sulcata*, Lamarck, Hist. nat. Anim. sans Vert., vol. ii, p. 231; Cuvier and Brongniart, Géographie Minéral. des Envir. de Paris, tab. ii, fig. 3. (Edwards and Haime, 1850, p. xvi, Middle Eocene, Paris basin.)

TURBINOLIA MIDWAYENSIS Monsour, n. sp.
Plate 21, figures 4, 5

Corallum conical; wall a true theca, thin. Costae very thin, high, and prominent, 24 in three cycles, showing faint development of a fourth between each row of pores in upper half of corallum. Tertiary costae half the length of corallum, secondary 0.25 mm. above primary which reach base.

Intercostal furrows deep and broad, perforated by double rows of very large pores. A small longitudinal lamina, most pronounced at calicular margin, separates each row of pores and disappears at end of tertiary costae. Septa weak and thin, 24 in number, in three cycles of six systems. Septa of first cycle slightly larger than those of second and third, fused directly with styliform columella. Septa of third cycle curve, fuse to first about one-third of distance from corallum wall to columella. Septa sparsely ornamented with minute spines on lateral surfaces.

Type: holotype, diameter of calyx, 2½ mm.; height of corallum, 4 mm.; Louisiana State University Paleontology Museum no. 4451.

Type locality: Clayton formation of the Midway group of Mississippi; upper "marl" member at Chalybeate Springs, about 2½ miles southeast of Walnut in sec. 3, T. 2 S., R. 4 E.; blue sandy somewhat fossiliferous marl (loc. 1).

Occurrence: Clayton formation of the Midway group of Mississippi.

Remarks: *T. midwayensis* differs from *T. acuticostata* Vaughan (Pamunkey formation of Maryland and Virginia) in that the latter has a hexagonal columella style; 48 crenate costae with slight enlargement at base; and the tertiary cycle of costae extends three-fourths of the length of the corallum.

TURBINOLIA TENUIS Monsour, n. sp.
Plate 21, figures 7, 8

Corallum conical, elongate. Wall a true theca, thin. Costae very thin, high, prominent from calicular margin to base. Costae 24, both primary and secondary prolonged to base with secondary 0.1 mm. above. Tertiary costae terminate within 1.0 mm. of base.

Intercostal furrows deep and broad, perforated by double row of very small, pinlike pores. Septa thin and weak, 24 in three cycles of six systems. Septa of primary cycle slightly larger than others, fused to rays of columella. Septa of tertiary cycle fused to primary halfway between corallum

wall and columella, their lateral surfaces slightly granulated with minute spines, particularly one-third of distance from corallum wall. Columella strongly stellate, projecting even with calicular margin.

Type: holotype, diameter of calyx, 2½ mm.; height of corallum, 5 mm.; Louisiana State University Paleontology Museum no. 4453.

Type locality: Lisbon formation, six feet above base; Little Stave Creek, Ala. (loc. 58).

Occurrence: Basal Claiborne to Moodys Branch marl of Texas, Louisiana, Mississippi, and Alabama. Localities 3–5, 7–13, 18, 20–27, 32, 34, 35, 39, 40, 42, 47, 51, 52, 56, 58–61, 63, 64, 66, 67, 69–73.

Remarks: This species differs from *T. pharetra* Lea in that the costae are persistently thin with no enlargement at the base. Also, this species differs from *T. clarki* Quayle (Eocene, Domengine formation of California) in that the latter has slightly enlarged and higher costae at the base. Range in size from minute to 2×7 mm.

TURBINOLIA TENUIS CONICA
Monsour, n. var.
Plate 21, figure 11

This variety differs from the type of the species in that the corallum has a true conical shape; no elongation.

Type: holotype, diameter of calyx, 3½ mm.; height of corallum, 6 mm.; Louisiana State University Paleontology Museum no. 4454.

Type locality: Topmost Stone City at Stone City P. O., Burleson Co., Texas; southeast bank of Brazos River, near Texas State Hy. 21 bridge; downstream and stratigraphically overlying loc. 14 (loc. 15).

Occurrence: Basal Claiborne to Moodys Branch marl of Texas, Louisiana, Mississippi, and Alabama. Localities 7, 9, 11–15, 17, 22, 23, 25–28, 30, 33–35, 38, 40, 48, 58, 66, 70, 73.

Remarks: Range in size from 1½×2 mm. to 3½×6 mm.

TURBINOLIA PHARETRA Lea
Plate 21, figures 9, 10

Turbinolia pharetra Lea, 1833, Contrib. to Geol., p. 196, pl. vi, fig. 210.
Turbinolia pharetra, de Gregorio, 1900, Mon. de la faune eocènique l'Ala., p. 254, pl. 44, figs. 12–19.
Turbinolia pharetra, Vaughan, 1900, U. S. Geol. Survey Mon. 39, pp. 86–88, pl. 6, figs. 5–10.
Turbinolia pharetra Quayle, 1932, San Diego Soc. Nat. History Trans., vol. 7, no. 10, pl. 6, figs. 17–19.

Shape elongate, conical. Wall a true theca. Costae 24 in number, rather prominent, rounded in profile but not flattened, margins simple, entire. At the calicular opening they are of equal size. Near the base 12 of the costae are larger, the intermediate ones becoming very insignificant; only 6 are prolonged to the basal tip. Intercostal furrows perforated by a double row of pores.

Septa moderately exsert, with entire margins, in three cycles, 24 in number, their surfaces granulate. Columella strong, terminated above in a hexagonal star, which projects slightly above the upper margins of the septa. The septa of the first cycle fuse to the rays of the star. (Vaughan, 1900, pp. 86, 87.)

Vaughan gives the geologic occurrence as "Upper and Lower Claiborne and Jacksonian stage." The writer has found this to be the most common species, ranging from the basal Claiborne (Tallahatta) to the basal Jackson (Moodys Branch marl) of Texas, Louisiana and Alabama. Localities 4–7, 9, 11–21, 23, 25–38, 40, 41, 45, 49–51, 53–55, 59, 61, 63–68, 70.

T. pharetra differs from *T. tenuis* in that the basal portion of the costal terminations are enlarged, the costae of *T. tenuis* being persistently thin with no enlargement.

TURBINOLIA WAUTUBBEENSIS Vaughan
Turbinolia wautubbeensis Vaughan, 1900, U. S. Geol. Survey Mon. 39, pl. VI, figs. 11, 12, pp. 88–89.

Shape conical, with a subobtuse base. Cross section circular. Costae 48 in number; 24 correspond to the 24 septa, and 24 are rudimentary costae. At the calicular margin the costae corresponding to the septa are all of the same size, while the rudimentary costae are smaller. As the base is approached the costae corresponding to the septa become much larger, and more prominent; about one-third of the distance from the calicular margin to the base the rudimentary costae become smaller; then all of the costae grow smaller until, about 1.3 mm. from the apex, those corresponding to the tertiaries becoming much finer. At this second enlargement the rudimentary costae disappear. The primary and secondary costae seem to continue to the apex of the base. All of the costae are rather compressed; their margins are entire and smooth. The intercostal furrows are perforated. The wall is rather thin. Septa 24, in three cycles, six systems, somewhat exsert, faces undulated, granular.

. . . Diameter, 4 mm.; height, 9 mm.; columella projects 1 mm. above the corallum wall. (Vaughan, 1900, pp. 88, 89.)

Vaughan gives the type locality of the species as Wautubbee, Mississippi; the geologic occurrence, lower Claiborne.

T. gigantissima differs from *T. wautubbeensis* in its more conical shape, costae persistently thin from calyx to base, septa greatly exsert, columella not projecting as far above the corallum wall, and columella being granulated.

TURBINOLIA SUBTERCISA Monsour, n. sp.
Plate 21, figures 2, 3

Corallum conical, elongate. Wall a true theca, thin. Costae 24, rounded in profile; primary costae prolonged to base, secondary reaching to within 0.1 mm., and tertiary to within 1.0 mm. of base.

Intercostal furrows narrow, perforated by two vertical rows of pores, one row visible, other beneath fluting of costae. Septa 24, thin and weak, in three complete cycles of six systems. Septa of primary cycle slightly broader or more flaring at upper margin than those of secondary and tertiary cycles; primary fused to rays of columellar star. Septa of tertiary cycle curve toward and fuse to those of primary cycle at one-half to two-thirds distance from corallum wall to columella. Lateral surfaces moderately granulated with small, distinct spines, particularly on half near corallum wall. Columella strongly stellate, projecting 0.3 mm. above calyx.

The distinctive feature of the species is the fluting at the base of the costae, particularly in the thicker primary and secondary cycles.

Type: holotype, diameter of calyx, 2½ mm.; height of corallum, 5 mm.; Louisiana State University Paleontology Museum no. 4449.

Type locality: Basal Cook Mtn. (Wheelock). Smithville, Bastrop Co., Texas; 200 yards east of bridge over Colorado River, immediately above the bentonite bed (loc. 20).

Occurrence: *T. subtercisa* has a wide distribution in the Gulf Coast sediments and a narrow stratigraphic range, being confined to the Cook Mtn. formation of Texas and Louisiana and its equivalent in Alabama—the Lisbon formation. Localities 20, 32, 39–46, 51, 55, 61.

Remarks: This species differs from *T. insignifica* (described by Vaughan from the Red Bluff beds) in that it has a strongly stellate instead of styliform columella, and has 24 costae instead of 20. *T. subtercisa* differs from *T. olssoni* Wells (middle Oligocene, Mamore formation of Peru) in that the latter has a styliform columella.

TURBINOLIA SUBTERCISA MAURICENSIS
Monsour, n. var.
Plate 21, figure 1

This variety differs from the type of the species in its thinner costae and broader intercostal furrow, also in a less elongate conical shape, a truncated calicular margin, and a sunken calyx.

Type: holotype, diameter of calyx, 2½ mm.; height of corallum, 4 mm.; Louisiana State University Paleontology Museum no. 4450.

Type locality: Type Saline Bayou member of the Cook Mountain, St. Maurice, La. (loc. 55).

Occurrence: Found only in the Saline Bayou member of the Cook Mountain formation of Louisiana (loc. 55).

TURBINOLIA SUBTERCISA LISBONENSIS
Monsour, n. var.
Plate 21, figure 6

This variety differs from *T. subtercisa* var. *mauricensis* in that it is more elongate, conical. The specimens, although worn, exhibit the characteristic feature of the type species—fluting of the costae.

Type: holotype, diameter of calyx, 2 mm.; height of corallum, 6 mm.; Louisiana State University Paleontology Museum no. 4452.

Type locality: Little Stave Creek, Ala.; six feet above the base of the Lisbon formation (loc. 58).

Occurrence: Lisbon and Gosport formations of Alabama. Localities 58 and 66.

Remarks: Size of corallum ranges from 2½×4 mm. to 2×6 mm.

TURBINOLIA GIGANTISSIMA
Monsour, n. sp.
Plate 21, figures 14, 15

Corallum conical, very large. Wall a true theca, thin. Costae 48 in four cycles, high, persistently thin from calicular margin to base. Costae of fourth cycle terminate 3.0 mm. from calyx, those of tertiary reach to within 1.0 mm. and those of secondary to within 0.25 mm. of base, primary costae reach base.

Intercostal furrows deep, narrow, perforated by double row of pores forming vertical grooves on surfaces of costae. Septa 24, in six systems, three cycles. Primary and secondary septa of same thickness, tertiary thinner. Primary septa fused to rays of columella; tertiary curved and fused to primary and secondary cycles that project above calicular margin to same height as columella; fan-like arrangements of laminae, on lateral surfaces, radiating outward toward arched peripheral outline of projecting septa. The large, stubby, coarsely granulated columella terminated by stellate apex, projecting 0.5 mm. above calyx.

Type: holotype, diameter of calyx, 5 mm.; height of corallum, 8 mm.; Louisiana State University Paleontology Museum no. 4456.

Type locality: Six feet above the base of the Lisbon at Little Stave Creek, Ala. (loc. 58).

Occurrence: Restricted to the Lisbon formation of Alabama (locs. 57–59).

Remarks: *Turbinolia gigantissima* differs from *T. wautubbeensis* Vaughan in its much more conical shape (5×8 mm.), costae persistently thin from calyx to base, septa greatly exsert, columella less prominent and not projecting as far above corallum wall, and granulations of the columella. *T. dickersoni* Nomland (Eocene, Meganos formation of California) differs from *T. gigantissima* in that the shape is less conical, columella not as prominent, and in the slight enlargements of the basal portions of the costae.

TURBINOLIA CLAIBORNENSIS Vaughan

Turbinolia claibornensis Vaughan, 1900, U. S. Geol. Survey, Mon. 39, pl. 6, figs. 14–16b, pp. 90–91.

Corallum small, conical, with acute delicate costae, the margins of which are entire. Around the calice there are 48 costae, 24 correspond to septa, and as many are rudimentary. The rudimentary costae are initiated about 3¼ mm. from the base. The costae of the first and second cycles are very slightly enlarged near the base of the corallum. There are three complete cycles of septa. Their surfaces are covered with distinct conical spines. The primary septa reach and fuse to the columella. The upper termination of the columella is not a star, but compressed, a little excavated on the sides below the upper surface, and slightly granulate. Height of corallum, 5 mm.; diameter, 3 mm. . . .

The distinguishing features of the species are the presence of (1) rudimentary costae; (2) the entire margins of the costae; (3) the simple enlarging, without a notch, of the costae in the basal portion; (4) the compressed granulate (not stellate) termination of the columella; (5) the size. (Vaughan, 1900, pp. 90, 91.)

Vaughan gives the type locality of the species as Claiborne, Alabama; the geologic occurrence as Claiborne sands.

The small corals found by the writer have only 12 to 24 costae instead of 48 as in *T. claibornensis*, and the columellae are stellate instead of possessing compressed granulated terminations.

TURBINOLIA INSIGNIFICA Vaughan

Turbinolia insignifica Vaughan, 1900, U. S. Geol. Survey, Mon. 39, pl. 6, figs. 17–18, pp. 91–92.

This is a minute coral, conical in shape. Costae rather tall, compressed, their sides near junction with corallum wall fluted, corresponding to intercostal perforations. Margins apparently almost smooth. Around the upper margin of the corallum there are 20 well developed costae and 20 rudimentary costae (twice as many as septa); 6 septa continue without any change to the very apex of the base. On the apex of the base is a minute star-like body, the rays of which alternate with the costae of the first cycle (i.e., the 6 more prominent costae). The costae of the second cycle are notched 0.5 or 0.75 mm. above the base. There are costae corresponding to the septa of the third cycle, and after the second cycle of septa is fully developed rudimentary costae usually exist. . . . The intercostal furrows are always perforated, and when the rudimentary costae are not present there are double rows of perforations.

A distinguishing feature of this species is that in the basal portion the costal terminations are not enlarged. Of the 12 costae that extend to the base, 6 do not change at all and 6 are simply notched about 0.5 mm. above the base.

The specimens are not well enough preserved to permit the details of the columella to be fully made out, but we can be sure that the upper termination is a style and not a strongly stellate pillar, . . . Diameter, 2 mm.; length, 3.5 mm.* * *

The character of the columella above noted, the peculiarities of the costae in its basal portion, and its very small size serve to distinguish this species. (Vaughan, 1900, pp. 91, 92.)

Vaughan gives the type locality of the species as Old Red Bluff Station, 3½ miles south of Shubuta, Mississippi; the geologic occurrence as Red Bluff beds.

This species differs from *T. subtercisa* in having a styliform columella and 20 costae instead of a strongly stellate columella and 24 costae.

T. insignifica and *T. vicksburgensis* illustrate the fact that the species of the Vicksburg group have styliform columellae, whereas those of the Claiborne and Jackson groups have stellate columellae.

TURBINOLIA VICKSBURGENSIS
Monsour, n. sp.
Plate 21, figures 12, 13

Corallum conical, elongate. Wall a true theca, thin. Costae 24 in three cycles, high, persistently thin from calyx to base. Fourth cycle costae developed at the calicular margin, becoming thin laminae and disappearing 3.0 mm. from calyx. Tertiary costae reach to within 2.0 mm. of base, secondary to within 0.5 mm., primary reach apex of base.

Intercostal furrows deep and narrow, perforated by double row of pores. Septa 24, weak and thin, in three cycles of six systems. Septa of first cycle broader than those of the second and third, fused to columella. Septa of third cycle curved, fused to first cycle halfway between corallum wall and columella. Septa moderately exsert, margins entire, lateral surfaces sparsely ornamented with minute spines. Columella slender, styliform, granulations few, projecting 0.5–1.0 mm. above calicular margin.

Type: holotype, diameter of calyx, 3 mm.; height of corallum, 9 mm.; Louisiana State University Paleontology Museum no. 4455.

Type locality: Mint Springs marl formation; falls nearest Mississippi River in Glass Bayou (adjoining National Park Cemetery) at Vicksburg, Mississippi; 3–10 ft. below 25 ft. limestone bed, 7 ft. bluish-gray sandy clay (loc. 77).

Occurrence: Vicksburg group of Louisiana, Mississippi, and Alabama. Localities 75–79, 81–84.

Remarks: This species differs from *T. gigantissima* by its elongate conical shape, and slender, less crenulated styliform columella. *T. vicksburgensis* also differs from *T. olssoni* Wells and *T. insignifica* Vaughan by its lack of fluting on costae, its more elongate, conical shape, and the greater projection of its columella. *T. insignifica* has 20 costae, whereas *T. olssoni* and *T. vicksburgensis* have 24.

This is the only species found by the writer in the Vicksburg Oligocene; it has the thin costae and styliform columella characteristic of the group.

Range in size from minute to 3×9 mm.

MANUSCRIPT RECEIVED APRIL 7, 1942.

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The author desires to express his most sincere gratitude to Dr. T. Wayland Vaughan, United States National Museum, for his kindness in checking two new species and at Dr. Vaughan's request representatives of these species, *Turbinolia gigantissima* and *T. vicksburgensis*, were deposited in the U. S. National Museum. Other species and varieties now represented in the U. S. National Museum collection are *T. subtercisa*, *T. subtercisa mauricensis*, *T. tenuis*, and *T. tenuis conica*.

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REVISION OF CAMPOPHYLLUM IN NORTH AMERICA

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ABSTRACT—Morphology and stratigraphic position of the types of Carboniferous species are presented. The status of each pre-Carboniferous species is reviewed. Generic relationships are discussed and *Bothrophyllum* and *Caninophyllum* are introduced into American systematics. *C. kansasense* = *Bothrophyllum? kansasense*; *C. nevadense* = *Caninia nevadensis*; *C. gasperense* and *Lithodrumus veryi* = *Caninia veryi*; *C. torquium* = *Caninia torquia*; *C.? readi* = *Caninophyllum? readi*. Previous use of *Caninia* is reviewed. No valid species of *Campophyllum* are recognized.

INTRODUCTION

THE genus *Campophyllum* Milne-Edwards and Haime, 1850 is based upon *Cyathophyllum flexuosum* Goldfuss, said to occur in the Devonian of Germany but probably occurring in the Carboniferous. Confusion regarding the nature of the genus *Campophyllum* began immediately after its diagnosis and has persisted, although this confusion has since been altered to mere uncertainty. *Campophyllum*, *Caninia*, and *Cyathophyllum* commonly have been confounded.

A number of American corals have been referred to the genus *Campophyllum*, chiefly on the basis of supposed cyathophylloid morphology. The purposes of this paper are to review the basic foreign literature, to discuss the characters of several pertinent genera, to show the present status of some genera involved, and to determine the genera to which certain described species heretofore referred to *Campophyllum* belong.

The historical portion of this study is given as briefly as possible because interested paleontologists will necessarily refer to the original works. The systematic portion involves an analysis of type specimens, when available, or analysis of published descriptions and plates, because the writer believes that his most valuable contribution lies in the clarification of the characters and taxonomic position of type material.

The synonymies presented in this paper are citations, rather than strict synonymies, because the writer in this instance has been interested chiefly in the extent of use of the different specific names, rather than in compiling references to strictly taxonomic studies.

The photographs on plate 22, figures 2–6, 9, 10, were made by using the technique previously described by the writer (Easton, 1942).

HISTORICAL SUMMARY

The consistent generic misidentification of American Carboniferous corals referred to *Campophyllum* seems to have arisen primarily because writers compared their material with that of Swallow, who introduced the genus into American literature, and secondarily because most of the American species are referable to related genera.

In an effort to clear up the relationship between *Campophyllum* and *Caninia*, Vaughan (1905, p. 276) contributed the following analysis:

> This genus [*Campophyllum*] is distinguished from *Caninia* by the following characters:—
>
> (1) Almost perfect radial symmetry, due to the uniformly-developed ring of short, thick septa.
> (2) The absence, or very feeble development, of a fossular depression.
> (3) The uniformly-thick shell of vesicles between the two walls.
> (4) The strongly-developed outer wall.

Carruthers (1909, p. 149) considered it impossible to differentiate between *Campophyllum* and *Caninia* from ephebic transverse sections and he considered *Campophyllum* intermediate between *Cyathophyllum* and *Caninia*. He previously (1908, p. 159) had demonstrated that *Cyathopsis* d'Orbigny, 1849 is a synonym of *Caninia*. Carruthers examined the genotype of *Campophyllum* in the Musee d'Histoire Naturelle in Paris and decided that the greatest difference between *Caninia* and *Campophyllum* occurred in the young stages, for, he says,

at this period, in *Caninia*, the septa reach the center of the corallum, and dissepiments have not yet appeared; whereas in a *Campophyllum*, from a very early stage onwards, the septa are short and amplexoid, and dissepiments apparent.

He concluded by agreeing that the separation of the two genera may not be advisable.

O'Connell (1914, p. 189) suggested reviving the genus *Siphonophyllia*

for forms like *Caninia gigantea* * * * which have numerous tabulae, a siphonofossula and a well-marked external vesicular zone.

Siphonophyllia had been founded by M'Coy (1844, p. 187) with *S. cylindrica* as genotype, but the genus has been rarely recognized since then. Incidentally, M'Coy spelled the name *Syphonophyllia* on the explanation of his plate.

Carruthers (1908, p. 165, diagram F, fig. 3) showed in plesiotypes of *Caninia cornucopiae* the downbending of the tabulae into the fossula, which is the chief morphological basis for *Siphonophyllia*.

Reed (1927, p. 27) questioned the availability of *Campophyllum*, but thought its retention advisable because of long use.

Grabau (1922, p. 14) published his opinion that

true *Caninia* never passes beyond the normal fossula in the adult, but *Siphonophyllia* passes through a *Caninia* stage, developing a siphonofossula in its own adult stage. A young *Siphonophyllia* may therefore be mistaken for a *Caninia*, unless its immature character is recognized.

Lang, Smith, and Thomas (1940, p. 120) do not agree with O'Connell and Grabau, but consider *Siphonophyllia* a synonym of *Caninia*.

Hill (1939, p. 103) seemingly considered *Siphonophyllia* to be available and *Palaeocaninia* Lissitzine, 1925 a junior synonym. Miss Hill (1939, p. 105) considered *Peetzia* Tolmatchoff, 1924 to be a synonym of *Caninia*.

Bell (1929, pp. 71, 72) believed that *Caninia dawsoni* (Lambe) might be classified as a *Campophyllum* from transverse sections through ephebic stages.

Smith (1935, p. 39) considered *Campophyllum* and *Siphonophyllia* to be synonymous genera founded on different species of *Caninia*.

Lang, Smith, and Thomas (1940, p. 30) did not offer an opinion as to the availability of *Campophyllum*, but stated that the genotype "exhibits characters intermediate between true *Caninia* Michelin and *Palaeosmilia* Edwards & Haime." They also (1940, p. 44) referred to *Cyathopsis*, which they considered a synonym of *Caninia*.

Hill (1940, p. 116) wrote,

C. flexuosum Goldfuss *non* Linnaeus *non* Edwards and Haime was renamed *C. aquisgranense* by Frech (1885, p. 27, p. 40), and his figured specimens (pl. ix, figs. 1a–c, pl. x, fig. 1) from the Upper Devonian [?Zone d'Etroeungt] of Stollberg near Aachen, are thought to represent a *Palaeosmilia*.

Thus, Miss Hill considers *Campophyllum* a probable synonym of *Palaeosmilia*, although she made no definite statement to that effect.

The most recent first-hand information concerning *Campophyllum* resulted from Schindewolf's study of the genoholotype (*fide* Lang, Smith, and Thomas, 1940, p. 30). He stated that the type species is a representative of *Caninia*. If we accept this opinion, *Campophyllum* must be considered a junior synonym of *Caninia*. If we do not, it still

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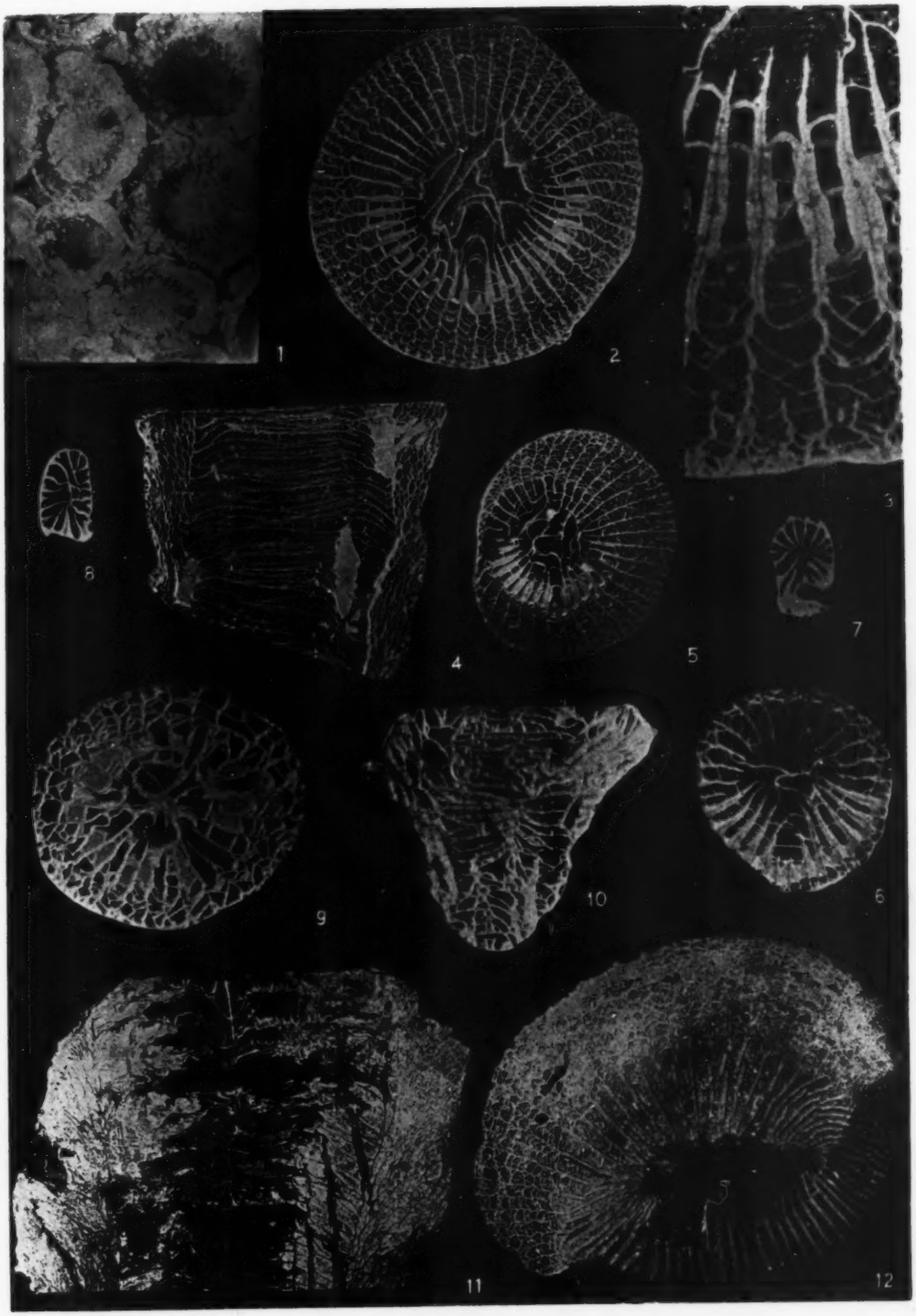
EXPLANATION TO PLATE 22

FIGS. *1—Caninia veryi* (Greene), ×0.75, portion of holotype copied from Greene (1904). (p. 128)

2–7—Caninia torquia (Owen). *2*, Transverse section, late ephebic stage, ×1.5, holotype, U. S. Nat. Mus. 17953. *3*, Transverse section enlarged from right cardinal quadrant of fig. 2 to show the nature of stereoplasmic thickening, ×6. *4*, Longitudinal section, ×1.5, holotype. *5*, Transverse section, middle ephebic stage, ×1.5, plesiotype, U. S. Nat. Mus. 6839. *6*, Transverse section, neanic stage, ×3, plesiotype, U. S. Nat. Mus. 6839. *7*, Transverse section, nearly ephebic stage, ×3, plesiotype, U. S. Nat. Mus. 6839. (p. 125)

8–10—Bothrophyllum? kansasense (Miller and Gurley). *8*, Transverse section, neanic stage, paratype, Univ. Chicago 6616. *9*, Transverse section, ephebic? stage, holotype, Univ. Chicago 47235. *10*, longitudinal section, holotype. All figures ×3. (p. 123)

11, 12—Caninophyllum? readi (Merriam). *11*, Longitudinal section, paratype, Cornell Univ. collections. *12*, Transverse section, ephebic stage, holotype, Cornell Univ. 38697. Both figures ×1.5. (p. 130)



Easton, *Campophyllum* in North America

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would be impossible to refer the described related American Carboniferous species to *Campophyllum* because each of them possesses a fossula.

Because paleontologists are not yet universally agreed as to the availability of *Campophyllum*, the detailed differentiation as understood by Vaughan (1901 (1903), pp. 102, 103) is quoted below in addition to his brief analysis which has already been presented:

> Those Zaphrentids which have a central area crossed by broad, close tabulae and in which each tabula has a deep depression near its circumference (the "fossula"), were separated by McCoy under the generic name *Caninia*. The convenience of this separation has been generally acknowledged, but the name *Caninia* has been discarded and replaced by the name Campophyllum.
>
> This is, in my opinion, a mistake caused by deceptive parallel-development.
>
> The essential characters of *Caninia* McCoy are the broad tabulae and the *deep* fossula; the presence of the fossula introduces a strong bilateral symmetry which, whenever the septa extend conspicuously over the tabulae, is rendered still more obvious by the Zaphrentis type of grouping.
>
> *Campophyllum*, Edwards & Haime, was created to cover a group of Cyathophyllids which have a broadly tabulate central area and short radical septa, not reaching the center; the strong radial symmetry and the very inconspicuous nature of the bilateral symmetry clearly indicate the close relationship of this group to the genus Cyathophyllum.
>
> Whenever, as is usually the case, the ring of short septa in a *Caninia* is not conspicuously continued over the tabulae towards the center, the general resemblance of the horizontal sections of *Caninia* and *Campophyllum* is remarkably striking, but in all cases the nature of the fossula forms a perfectly distinctive character for separating the two genera.
>
> In the horizontal sections of a *Caninia* the fossula is usually occupied by a short, unique septum, and is bounded by the two septa on either side, which converge round it and form an arch; usually also, one or more smaller arches lie within this main arch and indicate the intersections of the plane of section with the fossular depressions of higher tabulae.
>
> In the horizontal section of a *Campophyllum*, the bilateral symmetry is not conspicuous, but, as in a *Cyathophyllum*, is more or less marked out by the presence of one or more shorter septa at some point of the septal ring; the longer septa, however, on either side of the shorter ones, are straight and of normal pattern, and there is no indication of a depression in the floor of the tabula at this point.

Of the foregoing characters, the dubious fossula is the most important, because the others are more variable and are as much caninoid as cyathophylloid. Vaughan's statement above (1903) that "there is no indication of a depression in the floor of the tabula" where there are "one or more shorter septa" is not in complete agreement with his findings of 1905 as to the "absence, or very feeble development, of a fossular depression." In the opinion of the writer, a *Campophyllum* with a fossular depression is impossible, according to the diagnosis of *Campophyllum* by Milne-Edwards and Haime; such a combination of characters does answer for *Caninia*, however. This belief supports Salee, who (1910, p. 17) wrote, "Dans l'esprit des créateurs du genre *Campophyllum*, celui-ci était caractérisé notamment par l'*absence de fossette*."

The type of *Lithodrumus veryi* Greene, which is the genoholotype of *Lithodrumus* Greene, 1904 perhaps is lost,[1] however, the original generic description is reasonably good (Greene, 1904, p. 168). This genus differs from typical *Caninia* only by its compound habit and the presence of more than one fossula. These differences are not decisive, however, for compound specimens of *Caninia* are known, though they are uncommon, and a few specimens which the writer believes to be conspecific with *L. veryi* not only possess a cardinal fossula, but also have tabulae slightly reflexed in the counter or some other position, thus faintly suggesting a fossula although there is no aberration in disposition of septa to substantiate the presence of an extra fossula.

Also involved in this revision are *Pseudocaninia* Stuckenberg, 1888 and *Bothrophyllum* Trautschold, 1879. As pointed out by Hill (1939, p. 104) as a probability and by Lang, Smith, and Thomas (1940, p. 108) as an actuality, *Pseudocaninia* is an exact synonym of *Bothrophyllum*.

The writer has drawn the following conclusions from the original authors' researches:

1. *Campophyllum*, *Cyathopsis*, *Lithodrumus*, and *Siphonophyllia* are junior subjective synonyms of *Caninia*.
2. *Palaeocaninia* and *Peetzia* may be junior subjective synonyms of *Caninia*.
3. *Pseudocaninia* is a junior objective synonym of *Bothrophyllum*.

[1] H. E. Vokes, correspondence, May 6, 1942.

4. Only *Caninia* and *Bothrophyllum* are available genera and only *Caninia* has been reported previously from North America. The references are:

Caninia punctata d'Orbigny (1850, p. 105) was characterized as follows:

> Cette espèce magnifique de conservation m'a été envoyée par M. Beadle, sous le nom de *Cyathophyllum punctatum*. Etats-Unis, failles de l'Ohio (Cincinnati).

Aside from the description being a curiosity, the specimen undoubtedly came from Louisville and not Cincinnati. Milne-Edwards (1860, pp. 335, 336) considered this species synonymous with *Zaphrentis cornicula* Milne-Edwards and Haime and says it occurs at "ile Saint-Joseph dans le lac Huron et Indiana." Miller (1889, p. 176) considered the species unrecognizable.

Caninia sulcatum d'Orbigny (1850, p. 105) was considered by Miller (1889, p. 176) to be unrecognizable from the original description, but the specimen must have been preserved somewhere in Europe, for *Caninia sulcata* was made the genotype of *Aulacophyllum* Milne-Edwards and Haime, 1850. The type locality of this species was stated to be "failles de l'Ohio (Cincinnati), lac Erié," but no doubt it came from Louisville, Kentucky, rather than from Cincinnati. The original figure has been reproduced by Grabau and Shimer (1909, p. 59, fig. 87).

Caninia bilateralis Hall (1852, p. 41, pl. 17, figs. 3a–h; p. 113, pl. 32, figs. 3a–c) was subsequently known as *Zaphrentis bilateralis* (Hall) in Hall (1859, p. 79). Bassler (1915, p. 1334) records the species from the Silurian as *Zaphrentis*.

Caninia n. sp. was reported from the Paint Creek formation of Illinois by Stuart Weller (1920, p. 170).

Caninia dawsoni (Lambe) was reported by Bell (1929, pp. 91–94; pl. 2, figs. 3–3c; pl. 3, figs. 1–6a) from the Upper Windsor series of Nova Scotia. The species subsequently has been discussed by Lewis (1935, pp. 129–132) under the name *Caninia juddi* var. *dawsoni* (Lambe).

Caninia sp. was reported by Smith (1935, pp. 39, 40; pl. 9, fig. 11) from the Permian (or Upper Carboniferous) of British Columbia.

Caninia complexa Busch (1941, pp. 393, 399–401; figs. 28–33) was described from the Wanakah member of the Ludlowville formation and possibly from the Windom member of the Moscow formation (Hamilton) of New York.

Caninia tabulata Busch (1941, pp. 393, 401–403; figs. 34–40) was described from the Windom member of the Moscow formation (Hamilton) of New York.

Caninia sp. was figured by Jeffords (1942 fig. 2, p. 199) without an indication of its occurrence.

Caninia arcuata Jeffords (1943, p. 548, figs. 1–7) was described from the Alamogordo member of the Lake Valley limestone in the Osage series (Mississippian) from near Hillsboro and Lake Valley, New Mexico. The trivial name was also spelled *arcuta* by Jeffords.

SYSTEMATIC DESCRIPTIONS

Phylum COELENTERATA
Class ANTHOZOA
Order TETRACORALLA
Family CANINIIDAE

Genus BOTHROPHYLLUM Trautschold, 1879

Lewis (1931, p. 227), after studying Stuckenberg's description and figures of *Bothrophyllym conicum* and numerous Welsh specimens, gave the following diagnosis under the synonymous name *Pseudocaninia:*

> Simple Rugose Corals with a distinct Caninoid trend. The earlier stages in some respects resemble those of *Caninophyllum*, from which the genus differs (as it does also from *Caninia*) in that the longer septa are often fused together at their axial ends, so as to form in the proximal portion of the corallum a more or less definite "*pseudocolumella*." The fossula in the adult approximates to the Caninoid type, but in the earlier stages a pinnate arrangement of the major septa adjacent to the cardinal septum is conspicuous.

Genotype: *Bothrophyllum conicum* (Fischer) Trautschold.

Distribution: The genus is known from the British Isles, China, and also from several localities in Russia, where it has been discussed by Dobrolyubova (1937, pp. 25–49; English summary, pp. 75, 76) and by Kabakovich (1937, pp. 99–107) English summary, pp. 109–113).

BOTHROPHYLLUM? KANSASENSE
(Miller and Gurley)
Plate 22, figures 8–10

1894. *Campophyllum kansasense* Miller and Gurley, Illinois State Mus. Natural History, Bull. 3, pp. 67, 68, pl. 7, figs. 19–22.
1898. *Campophyllum kansasense.* Weller, U. S. Geol. Survey, Bull. 153, p. 161.

External character.—Simple, irregularly ceratoid corallites with cone-in-cone rejuvenescence; calyx moderately deep and flaring to moderately steep-walled; no calicular boss but the floor is crossed by several septa which join axially; epitheca thin and not characterized by marked septal grooves or interseptal ridges. Length about 2 cm.; greatest width about 1.5 cm.

Transverse sections.—In a section through ephebic (?) stage (diameters 15 by 13 mm.) tabularium crossed by 26 primary septa, about half of which unite weakly at the axis; two septa (cardinal-counter?) form a median septum or plate; a very few quite short septa partially enter the dissepimentarium; dissepimentarium occupying one-third of the radius and formed chiefly of herringbone but partially of concentrically arranged dissepiments without any seeming restricted location for each pattern; about 6 ranges of dissepiments, of which those near tabularium are somewhat crowded; fossula obscure or lacking; septal dilation lacking.

In neanic stage (diameters 4 by 2.5 mm.) a section shows no indication of tabulae or dissepiments; 14 primary septa extend nearly or quite to the axis; secondary septa very short or merely occurring as septal ridges; median septum or plate indicated.

Longitudinal section.—Dissepimentarium first appearing at a diameter of 5 mm.; tabulae concave, or convex and arched distally at the location of the median septum; axial structure weak or lacking except for median plate, which is discontinuous.

Remarks.—This species was based upon three specimens originally described without sections and compared with the admittedly dissimilar *Campophyllum torquium.* Figures 19 and 22 of Miller and Gurley (1894, pl. 7) represent the specimen sectioned by the writer and hereby designated the holotype, whereas, figures 20 and 21 of that publication now automatically become different paratypes; the explanation of plate 7 of that publication is in error with regard to the identity of the specimens.

This species is neither a *Campophyllum* nor a *Caninia*, but may represent a new genus closely related to *Bothrophyllum.* In a previously published abstract of this paper (Easton, 1941, p. 1966), it was suggested that this was seemingly a new genus, however, the present tentative reference is suggested because adequate material to enable further study is not available, yet this species in its mature (?) stage is morphologically similar to immature stages of *B. conicum.*

Locality.—"Upper Coal Measures" at Kansas City, Missouri. The exact stratigraphic position cannot be determined from information preserved concerning the types, however, it is reasonable to assume that the material came from the Kansas City group.

Material.—The only specimens known to the writer are the holotype, Walker Museum No. 47235, and the two paratypes, Walker Museum No. 6616.

Genus CANINIA Michelin in Gervais, 1840

Carruthers (1908, p. 158) redefined *Caninia* as follows, basing his diagnosis upon type material from Tournai, Belgium:

> *Corallum* simple, turbinate and conical, often slender and cylindrical for a great part of its length.
> *Major septa* well developed and meeting in the center in the lower, conical part of the coral, but in the cylindrical portions usually becoming amplexoid in character.
> *Minor septa* of various lengths in different species.
> *Cardinal fossula* variable in extent, characteristically limited by tabulae only, at the inner end, and with flanking septa loose or disconnected.
> *Tabulae* well developed, but variable in regularity; they may be highly arched and vesicular. A marginal ring of more or less vertical *dissepiments*, usually thin and delicate, intervenes in the mature stages of growth between the tabulae and the wall.

Short discussions of *Caninia* have appeared in this journal in articles by Smith (1935, pp. 38, 39), by Busch (1941, p. 399), and by Jeffords (1943, pp. 545, 547, 548).

Caninia may be separated into several species-groups, the best known of which

are the following, designated by the trivial name of the typical species:

1. *C. cornucopiae;* characterized by Hill (1939, p. 106) as follows:

> The corallum is variable, conical at first, cylindrical later; the epitheca bears numerous fine annulations and frequent growth-constrictions. The major septa number 32 at a diameter of 15 or 20 mm.; in the conical phase they are dilated, and are connected in groups which reach the axis, the cardinal fossula is very marked and deep, and the counter septum very long; then the major septa become less dilated in the counter quadrants and radially arranged, and very short minor septa appear; later, domed tabulae appear and the septa in the cardinal quadrants become thinner. In the cylindrical phase the septa withdraw from the axis, the tabulae flatten, and a single impersistent series of dissepiments is developed.

This species-group is represented in North America by *C. arcuata* Jeffords, and possibly by *C. complexa* Busch and *C. tabulata* Busch.

2. *C. benburensis;* characterized by Hill (1939, p. 112) as follows:

> Large *Caninia* with a dissepimentarium in which the major septa are usually continuous, and the minor septa usually discontinuous, being present only as ridges on the dissepiments. The dissepiments either traverse the whole major septal loculus, or meet at an angle near the middle; in the former case they are very slightly concave or convex, and in the latter they are quite straight; the former type is prominent in D_1 forms and the latter in D_2 forms. Occasionally a convex dissepiment may extend over more than one loculus. The major septa extend more than half-way to the axis, and are dilated in the tabularium. The fossula is deepest at the junction of the tabulae and disseptimentarium, and its floor is steeply inclined.

3. *C. juddi;* characterized by Hill (1939, p. 108) as,

> Large cylindrical *Caninia;* the dissepimentarium is about one-third as wide as the radius of the corallum, and is typically of inosculating dissepiments; the major septa are continuous throughout, but the minor septa withdraw toward the periphery in the adult stages.

This species-group is very wide-spread and of long range. It is represented in America by *C. dawsoni* (Lambe), *Caninia* sp. described by Smith, *C. torquia* (Owen), and probably by *C. veryi* (Greene).

4. *C. cylindrica;* the group is said by Lewis (1924, p. 390) to differ from *C. juddi* Thomson chiefly by the discontinuity of the major septa across the dissepimental zone, the greater number of septa possessed at the adult stage, and by the more open spacing of the tabulae.

5. *C. subibicina;* the ontogeny is not fully known, however, Hill (1939, p. 106) says of it that,

> Its dissepimentarium closely resembles that of *Clisiophyllum* and *Aulophyllum*, and it may be that the species is related to the Clisiophyllidae rather than to the Caniniidae.

Caninia nevadensis (Meek) resembles very closely the section of the type of *Caninia subibicina* M'Coy figured by Garwood (1913, pl. 49, fig. 3) and very likely belongs in this species-group.

There is some feeling that these species-groups should be given the rank of genera, however, *Caninia* as now understood forms a group of easily recognized and undoubtedly related species. It is dubious if splitting of the genus would serve any useful purpose.

Genotype: *Caninia cornucopiae* Michelin.

Occurrence: Carboniferous of many parts of the world, best known in Belgium, Britain, France, and Russia.

Caninia nevadensis (Meek)
Text figures 1a, b

1877. *Cyathophyllum* (*Campophyllum?*) *Nevadense* Meek, U. S. Geol. Expl. 40th Par., vol. 4, pt. 1, p. 60, pl. 5, figs. 3–3b.
1898. *Cyathophyllum nevadense.* Weller, U. S. Geol. Survey, Bull. 153, p. 204.
1905. *Cyathophyllum* (*Campophyllum?*) *nevadense.* Merrill, U. S. Nat. Mus., Bull. 53, pt. 1, p. 191.
1920. *Cyathophyllum nevadense.* Girty, U. S. Geol. Survey, Prof. Pap., No. 111, Appendix, p. 65, pl. 52, fig. 3.

Remarks.—The holotype (U. S. National Museum No. 24544) is not available at this time for study, therefore, the following analysis is made from Meek's description and plates.

External characters.—Simple, curved ceratoid to cylindrical corallites; no axial boss; calyx very deep and nearly vertically-walled in the lower portions and flaring distally; there may be about 50 septa of each order; length (incomplete) of outer curve of corallum is 15 cm.

Transverse section.—The figured section is at an ephebic stage (diameters 36 by 39 mm.). Tabularium crossed by 45 major un-

dilated septa slightly more than one-half radius in length; minors one-third to one-half as long as majors; dissepimentarium occupying one-fifth the radius; dissepiments in 5 or 6 ranges apparently all concentric in pattern; fossula indicated by arching of lateral septa adjacent to the presumed cardinal septum.

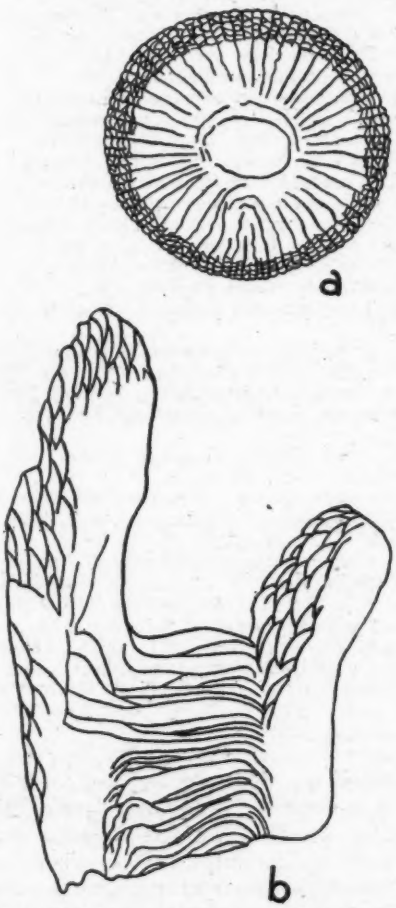

FIG. *1-a*, transverse section, cardinal septum probably at bottom of figure. *b*, Longitudinal section. Both figures after Meek, ×1.

Longitudinal section. — Dissepiments steeply inclined; tabulae slightly concave distally, reflexed at their peripheries, 10 per cm., complete.

Remarks.—Meek did not compare his single specimen with any other species and he was undecided whether it belonged to *Cyathophyllum*, *Campophyllum*, or *Zaphrentis*. This species is a *Caninia*, but the description and figures are inadequate to demonstrate absolutely whether it is distinct from other described species. The young stages are unknown.

Locality.—The holotype is from "Box-elder Peak, Wasatch Range, Utah; Carboniferous."

CANINIA TORQUIA (Owen)
Plate 22, figures 2–7

1843. *cyathophyllum vermiculare* Goldfuss. Nicollet, 26th Cong., 2d sess., S. Doc. 237 (1841), p. 31.
1843. *Cyathophyllum vermiculare* Goldfuss. Nicollet, idem, p. 169.
1845. *cyathophyllum vermiculare* Goldfuss. Nicollet, 28th Cong., 2d sess., H. Doc. 52, p. 31.
1845. *Cyathophyllum vermiculare* Goldfuss. Nicollet, idem, p. 169.
1852. *Cyathophyllum* (*vermiculare?*) Goldfuss. Owen, Geol. Rept. Wisconsin, Iowa, and Minnesota, tab. 4, fig. 2.
1852. *Cyathophyllum torquium* Owen, Geol. Rept. Wisconsin, Iowa, and Minnesota, tab. 4, fig. 2.
1852. *Cyathophyllum flexuosum* (?). Owen, Geol. Rept. Wisconsin, Iowa, and Minnesota, tab. 4, figs. 3a–b.
1855. *Campophyllum torquium*. Swallow, Missouri Geol. Survey, First and Second Ann. Repts., Appendix B, p. 216.
1872. *Campophyllum torrquium*. Meek, 42d Cong., 1st Sess., H. Doc. 19, p. 145, pl. 1, figs. 1a–d.
1873. *Campophyllum torquiam*. Broadhead, Coalfields of Missouri, pt. 2 (1872), p. 96.
1873. *Campophyllum torquium*. Broadhead, idem, pp. 103, 106, 108, 320, 416.
1873. *Campophyllum Torquium*. Broadhead, idem, p. 140.
1873. *Camphophyllum torquium*. Broadhead, idem, p. 423.
1884. *Campophyllum torquium*. White, 13th Rept. Indiana Geol. Survey, p. 119, pl. 23, figs. 10–13.
1889. *Campophyllum torquium*. Miller, North Am. Geol. and Paleontology, Cincinnati, p. 176, figs. 147, 148.
1890. *Campophyllum torquium*. Cummins, Texas Geol. Survey, Second Ann. Rept. (1889), p. 393.
1891. *Cyathophyllum torquium*. Keyes, Acad. Nat. Sci. Philadelphia, Proc., p. 244.
1893. *Campophyllum torquium*. Drake, Texas Geol. Survey, Fourth Ann. Rept. (1892), pp. 401, 402.
1894. *Campophyllum torquium*. Keyes, Missouri Geol. Survey, vol. 4, p. 107, pl. 12, figs. 7a–c; pl. 13, fig. 7.
1896. *Campophyllum torquium*. Bennett, Kansas University Geol. Survey, vol. 1, Chap. 15, p. 271.
1897. *Campophyllum torquium*. Prosser, Jour. Geol., vol. 5, no. 2, p. 157.

1898. *Campophyllum torquium*. Beede, Kansas University Quart., vol. 7, pp. 187, 188, text-figs. 1–4 on p. 190.
1898. *Campophyllum torquium*. Haworth, Kansas University Geol. Survey, vol. 3, pp. 37, 46, 64.
1898. *Campophyllum torquium*. Kindle, Indiana Geol. Survey, 22d Ann. Rept. (1897), p. 410.
1898. *Campophyllum torquium*. Weller, U. S. Geol. Survey, Bull. 153, p. 161.
1900. *Campophyllum torquium*. Beede, Kansas University Geol. Survey, vol. 6, pt. 2, pp. 19, 20, pl. 4, fig. 1; pl. 5, figs. 1–4.
1900. *Campophyllum torquium*. Beede and Rogers, Kansas University Bull., vol. 1, no. 8 (Kansas University Quart., vol. 9, no. 4), pp. 240, 242, 253.
1901. *Campophyllum torquium*. Udden, Iowa Geol. Survey, vol. 11, Adm. Repts., pp. 223, 224, 231.
1902. *Campophyllum torquium*. Beede, Kansas University Sci. Bull., vol. 1, no. 7 (vol. 11, no. 7 of series), pp. 164, 172.
1903. *Campophyllum torquium*. Adams, Girty, and White, U. S. Geol. Survey, Bull. 211, pp. 30, 63, 77.
1903. *Campophyllum torquium?*. Adams, Girty, and White, U. S. Geol. Survey Bull. 211, p. 63.
1903. *Campophyllum torquium*. Barbour, Nebraska Geol. Survey, vol. 1, pp. 122, 127, pl. 2, fig. 3.
1903. *Campophyllum torquium*. Girty, U. S. Geol. Survey Prof. Paper 16, pp. 236, 237, 247, 250, 257, 258, 323.
1903. *Campophyllum torquium*. Udden, Iowa. Geol. Survey, vol. 13, Ann. Rept. (1902), p. 160.
1904. *Campophyllum torquium*. Beede and Rogers, Kansas University Sci. Bull., vol. 2, no. 15, (vol. 12, no. 15 of series), pp. 464, 466, 470.
1904. *Camphophyllum torquum*. Reagan, Indiana Acad. Sci. Proc., (1903), p. 238, pl. on p. 245, figs. 2a–2c.
1904. *Camphophylum torquum*. Reagan, idem, (1903), p. 244.
1906. *Campophyllum torquium*. Beede and Rogers, Kansas University Sci. Bull., vol. 3, no. 10 (vol. 13, no. 10 of series), p. 377.
1906. *Campophyllum torquium*. Woodruff, Nebraska Geol. Survey, Rept., vol. 2, pt. 2, p. 260, pl. 5, fig. 3.
1908. *Campophyllum torquium*. Beede and Rogers, Kansas University Geol. Survey, vol. 9, chap. 9, pp. 339, 353, 362, pl. 43.
1909. *Campophyllum torquium*. Grabau and Shimer, North Am. Index Fossils, vol. 1, p. 67, fig. 102.
1910. *Campophyllum torquium*. Raymond, Carnegie Mus. Ann., vol. 7, no. 1, pp. 144, 154.
1910. *Campophyllum torquium*. Shimek, Iowa Geol. Survey, vol. 20, Ann. Rept., 1909, p. 302.
1912. *Chonophyllum torquium*. Crook, Illinois State Mus. Natural History Rept. for 1909 and 1910, pt. 3, p. 466.
1915. *Campophyllum torquium?*. Girty, Missouri Geol. Survey, ser. 2, vol. 13, chap. 8, table opp. p. 268.
1915. *Campophyllum torquium*. Girty, idem, tables, pp. 292, 302, 320–322.
1915. *Campophyllum torquium*. Mather, Denison University Bull., vol. 18, pp. 93, 94, pl. 1, figs. 14, 14a.
1919. *Campophyllum torquium*. Moore, Am. Assoc. Petroleum Geologists Bull., vol. 3, pp. 226, 233.
1920. *Campophyllum torquium*. Tilton, Iowa Geol. Survey, Ann. Repts. for 1919 and 1920, vol. 29, pp. 248, 310, 311.
1924. *Campophyllum torquium*. Morgan, Bur. Geol. (Oklahoma), Bull. 2, pl. 30, figs. 2–2b.
1925. *Campophyllum torquium*. Decker, Oklahoma Geol. Survey, Bull. 35, p. 66.
1926. *Campophyllum torquium*. Shimer, Canada Dept. Mines Bull. 42, pp. 5, tables opp. 6, 7, 24.
1927. *Campophyllum torquium*. Condra, Nebraska Geol. Survey, ser. 2, bull. 1, pp. 45, 46.
1927. *?Campophyllum torquium*. Warren, Canada Dept. Mines, Geol. Survey Mem. 153, p. 36.
1929. *Campophyllum torquium*. Roth, Oklahoma Geol. Survey, Circ. 18, pl. opp. p. 16.
1933. *Compophyllum torquium*. Condra, Nebraska Geol. Survey Paper 2, p. 13.
1933. *Campophyllum torquium*. Condra, idem, p. 15.
1933. *Campophyllum torquium*. Condra and Upp, Nebraska Geol. Survey Paper no. 3, pp. 12, 13.
1935. *Campophyllum torquium*. Newell, Kansas University Bull. 21, pp. 47, 86, 109, 110, 112, 113.
1936. *Campophyllum torquium*. Moore, Kansas University Bull. 22, p. 176.
1937. *Campophyllum torquium*. Condra and Reed, Nebraska Geol. Survey, ser. 2, Bull. 11, pp. 8, 17, 21, 27, 35, 57.
1938. *Campophyllum torquium*. Lee, *et al.* Texas University Bull. 3801, pp. 21, 49, 154, 155, 157, 158, 172–174, 176, 183, 184, 186, 188, 220.
1938. *Campophyllum* cf. *C. torquium*. Lee, *et al.*, Texas University Bull. 3801, pp. 157, 176.
1939. *Campophyllum torquium*. Johnson, in Condra and Scherer, Nebraska Geol. Survey Paper 16, p. 17.

External characters.—Simple, curved to contorted, ceratoid to cylindrical corallites; calyx moderately deep and flaring, floor more or less flat, without calicular boss; epitheca moderately thick, when unweathered with transverse striations, rugae, and bourrelets, but apparently without true septal grooves or interseptal ridges; corallites variable in length, commonly from 3 cm. to about 30 cm.

Transverse sections.—Holotype in late ephebic stage (diameters 33 by 40 mm.), with tabularium partially crossed by 45 major septa, of which 24 in cardinal quadrants are much more dilated than remainder; septa within dissepimentarium equally thin

and sinuous in all quadrants, but at most only broadly curved within the tabularium; cardinal septum much shorter and counter septum slightly longer than others; major septa two-thirds as long as radius, minor septa about one-fourth as long as majors; dilated majors consist of thin medium septa proper with lateral sclerenchyme which may separate from the septa proper on one or both sides giving a bifid or trifid appearance to cardinal septa; dilation of rims of tabulae, therefore, causes apparent septal dilation; dissepimentarium occupying one-third of radius and consisting of both herringbone and concentric patterns in 12 to 14 ranges, the outermost 3 or 4 ranges lying between major and minor septa and being mostly of concentric pattern; tabulae convex distally, about six reflexed sharply into cardinal fossula; septa adjacent to cardinal fossula curving into rough parallelism with the counter-cardinal plane.

One of Meek's plesiotypes (diameters 35 by 38 mm.) has 44 majors, 24 of which are dilated; dissepimentarium occupying slightly less than one-half the radius and there is an average of 15 ranges of dissepiments exclusively herringbone in pattern, except between some majors and minors where they may be concentric.

Another of Meek's plesiotypes furnishes the ontogeny of this species. In neanic stage (diameters 3 by 5 mm.) there are 16 dilated septa almost joining axially. The cardinal septum is short and there is one truncate tabula at the cardinal position. The dissepimentarium consists of one incomplete range of dissepiments.

In early ephebic stage of the same pleisiotype (diameters 10 by 10 mm.) with 27 major septa, the 13 in cardinal quadrants dilated and two-thirds of the radius, others not more than one-half the radius; minors about 1 mm. long, not extending within the tabularium; cardinal fossula occupied by two short dilated septa around which adjacent lateral septa arch; tabulae reflexed into fossula; dissepiments in three ranges occurring only between major and minor septa; concentric pattern predominant but with mixture of herringbone.

In middle ephebic stage of the same plesiotype (diameters 21 by 25 mm.) with 35 major septa, the 18 in cardinal quadrants much dilated, but all majors of about equal length and three-fourths as long as the radius; minors about 2 mm. long, except on side adjacent to geniculation of corallite, where they are merely septal ridges; dissepimentarium one-half as long as radius or less, consisting largely of herringbone pattern but concentric pattern predominates between majors and minors; tabulae sharply reflexed into cardinal fossula.

Longitudinal sections.—Holotype with density of 26 tabulae per cm.; tabulae slightly concave distally, reflexed proximally, slightly thicker at their peripheries, both complete and incomplete. Meek's first plesiotype redescribed above has density of 20 both complete and incomplete tabulae per cm.; tabulae slightly concave distally, reflexed proximally at their peripheries.

Remarks.—Meek (1872, p. 146) wrote that,

> In some respects our coral seems nearly related to *Caninia sub-ibicina* of McCoy * * * but it has not near so many septa.

Girty (1915, p. 231) questioned the correctness of referring this species to *Campophyllum* and considered it possibly related to *Craterophyllum verticillatum* Barbour, which Lang, Smith, and Thomas (1940, p. 26) renamed *Barbouria* because of the priority of *Craterophyllum* Foerste, 1909. *B. verticillata* (Barbour) resembles *Aulina furcata* Smith (1925, pl. 24, figs. 3–7; text-figs. of p. 491) and *Diphyphyllum a* (see Smith, 1928, p. 115). Before *Barbouria* can be usefully or authentically employed, the genotype must be figured more adequately.

Caninia torquia is abundant at some localities in the Pennsylvanian and Moore (1933, p. 342) says it locally may constitute most of a deposit. Furthermore, this coral may "become two feet or more in length, and from two to three inches in diameter," according to Worthen (1873, p. 315). The specimens presumably mentioned by Worthen are now deposited at the Illinois State Geological Survey in the Worthen collection, no. 4067. Although incomplete and not two feet long, these specimens are remarkably large, one having a maximum diameter of 5.2 cm.

Additional study will probably reveal that more than one species is now included in *C. torquia* of authors.

Occurrence.—This species has an extensive stratigraphic and geographic range in the Pennsylvanian. The holotype was reported to have been collected from limestone that now no longer exposed, near the mouth of Keg Creek, Iowa. Condra[2] reports that the Beil limestone member of the Lecompton, a few feet higher than the Plattsmouth, crops out nearby and contains abundant *C. torquia*. The Beil consists of upper and lower limestone members separated by shale. Both the shale and upper limestone carry these corals. Condra is of the opinion that the types

were not found on Keg Creek proper but came from the Missouri River bluffs southeast of Pacific Junction, at a point south of Keg Creek.

Because the holotype is remarkably clean, it is reasonable to assume that it came from the calcareous shale in the Beil limestone.

Meek's plesiotypes sectioned by the writer were collected from the Upper Coal Measures at Rock Bluff and Cedar Bluff, Nebraska.

Material.—The holotype is U. S. National Museum No. 17953. The sectioned plesiotypes are part of U. S. National Museum lot No. 6839.

CANINIA VERYI (Greene)

Plate 1, figure 1; text figs. 2a, b

1904. *Lithodrumus Veryi* Greene, Contr. Indiana Paleontology, pt. 17, pp. 168, 169, pl. 49, lower fig.
1922. *Campophyllum Gasperense* Butts, Kentucky Geol. Survey, ser. 6, vol. 7, p. 160.
1922. *Campophyllum gasperense* Butts, idem, pp. 162–164; figs. 2, 3 on p. 136; figs. 4–6 on p. 156; pls. 78A–B on p. 163; pl. 78C on p. 164; pl. 78D on p. 165.
1926. *Campophyllum gasperense.* Butts, Alabama Geol. Survey, Spec. Rept. 14, p. 187, pl. 62, figs. 2–7; pl. 49.
1927. *Campophyllum gasperense.* Weller, Kentucky Geol. Survey, ser. 6, vol. 28, p. 112.
1929. *Campophyllum gasperense.* Butts, Jour. Geol., vol. 37, no. 1, pp. 33, 34, 36, 38–41, figs. 1–5 on p. 44.
1932. *Campophyllum gasperense.* Weller and Sutton, Jour. Geol., vol. 40, no. 5, pp. 433–437, 439.
1935. *Campophyllum gasperense.* Lewis, Ann. Mag. Natural History, ser. 10, vol. 16, no. 91, p. 122.
1938. *Campophyllum gasperense.* Stouder, Am. Assoc. Petroleum Geologists Bull., vol. 22, no. 3, pp. 271, 273.
1940. *Campophyllum gasperense.* Butts, Virginia Geol. Survey Bull. 52, pt. 1, pp. 379, 381.
1940. *Lithodrymus veryi.* Lang, Smith, and Thomas, Index of Palaeozoic coral genera, British Mus. (Nat. Hist.), p. 78.
1941. *Campophyllum gasperense.* Stouder, Kentucky Geol. Survey (and Ky. Oil and Gas Assoc.), ser. 8, Bull. 7, pp. 20, 21, 26.
1942. *Campophyllum? gasperense.* Butts, Virginia Geol. Survey, Bull. 52, pt. 2, p. 249, pl. 132, figs. 12, 13.

External characters.—Simple ceratoid corallites or compound fasciculate, somewhat dendritic to massive cerioid coralla; cone-in-cone rejuvenescence present at least occasionally in simple corallites, but massive coralla exhibit intermural increase; calyx deep, nearly vertically-sided; calicular floor slightly concave except where interrupted by very deep fossula; floor partially crossed by some septa, traces of median septum may be present even in mature stages; epitheca moderately thick, marked by septal grooves and interseptal ridges, by rugae and bourrelets, and (possibly only rarely) by rootlets; dimensions of Butts' (1922, p. 162) largest specimen: diameter 32 mm., length of corallites 150 mm.

Transverse sections.—Tabularium in ephebic stage (diameters 20 by 23 mm.) three-quarters crossed by 30 major septa, of about equal length, not dilated within tabularium, weak and sinuous within dissepimentarium; infrequent very short septa extend about 1 mm. axially from epitheca; dissepimentarium occupies almost one-half the radius, formed of 6 or 7 ranges of rather large, irregular dissepiments in concentric and herringbone patterns, with lonsdaleoid dissepiments also present; fossula indicated by truncation of tabulae and shortening of cardinal septum; septa in cardinal quadrants slightly thicker than elsewhere.

No neanic section available. Silicified material at external diameter of 4 mm. shows no dissepiments, no indication of a fossula; tabulae convex distally, the 18 septa about 0.6 mm. long.

At external diameter of 8.5 mm. in another specimen two ranges of dissepiments are present; tabulae convex with depression at cardinal fossula; cardinal and counter septa continuous and joined by the two alars at the axis; 20 septa present in all.

[2] G. E. Condra, correspondence, May 25, 1942.

Longitudinal section.—Tabulae unequally spaced, concave to slightly convex, mostly complete though sloping in section, bent proximally at their peripheries; density of 16 or 17 tabulae per cm. but variable (as few as 9 indicated in a specimen figured by Butts); dissepiments steeply sloping.

Remarks.—This species is known only from silicified specimens, which, when sectioned, commonly fail to reveal internal details.

The writer believes that *L. veryi*, designated by Greene (1904, p. 168) as the genotype of *Lithodrumus*, is synonymous with *Campophyllum gasperense* Butts. Similarity of habit, known morphology and geologic position all lead to this conclusion. Unfortunately, the holotype of *L. veryi* Greene may be lost. If it is not found when museum collections are restored to order, neotypic material should be designated for comparative purposes. In making the foregoing analysis the writer has used Butts' type specimens for *Campophyllum gasperense*, as well as other specimens from Kentucky and Tennessee.

The type locality of *L. veryi* was stated to be "St. Louis group (sub-Carboniferous) four miles southeast of Mammoth Cave, Kentucky." According to Mr. J. M. Weller,[3] strata ranging from the Ste. Genevieve limestone to the Cypress sandstone occur in that region. Included are rocks of Renault age, from which the coral *Campophyllum gasperense* has been so frequently reported. Because the Renault there rests upon Lower Mississippian limestone, it was formerly included in the "St. Louis group."

Lewis (1935, p. 122) considered that *Campophyllum gasperense* Butts closely resembles *Caninia juddi* var. *dawsoni* (Lambe) and that possibly "*C. gasperense* is a later phaceloid development of the *C. juddi* stock."

Locality.—The holotype of this species is probably from the Renault formation of Chester age. It is known from the lower part of the "Gasper" oolite, or Renault limestone, in Alabama, Kentucky, Tennessee, and Virginia. According to the most recent detailed stratigraphic work by Stouder (1938, p. 271), the range is from the base to the top of the Renault, a vertical distance of 55 feet. The plesiotype, text fig. 3, was collected by Mr. W. Hagan, 8 or 10 feet above the base of the Renault, 0.5 mi. northeast of Spurrier Mills, Hardin Co., Kentucky. The plesiotype, text fig. 4, collected by Mr. Charles Butts, is from 3 mi. northeast of Livingston, Tennessee.

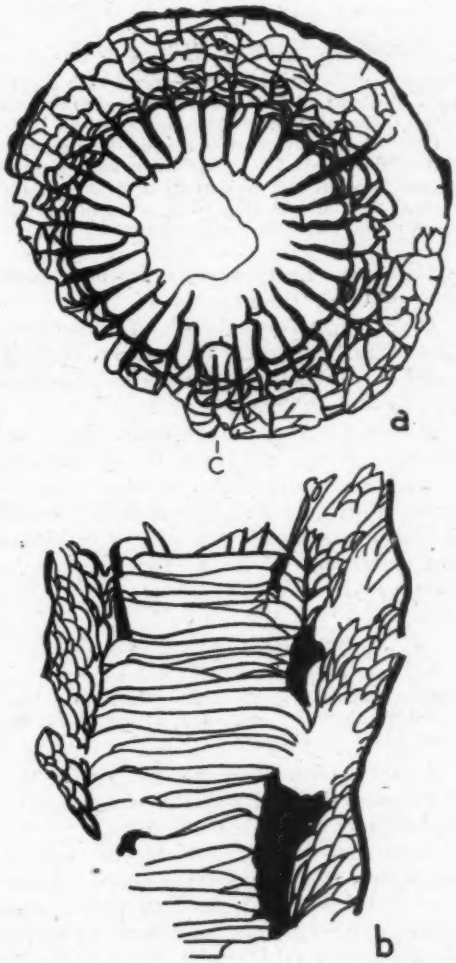

FIG. 2-*a*, *b*, Transverse section, ephebic stage, plesiotype, University of Illinois collections. *b*, Longitudinal section, plesiotype, U. S. National Museum, Butts locality No. 556E. ×2.5.

Material.—The holotype, which may be lost, should be in the Greene collection at the American Museum of Natural History, New

[3] J. M. Weller, Personal communication.

York. Butts' types are in the U. S. National Museum, Washington, D. C. The sectioned plesiotypes are in the University of Illinois and U. S. National Museum collections.

Genus CANINOPHYLLUM Lewis, 1929

Diagnosis.—(Lewis, 1929, p. 457).

Simple, cyathophyllid rugose corals with a caninoid trend, which finds expression in septal thickening, a conspicuous fossula, and, as a rule, broad tabulae. Normally there is a wide dissepimental zone of fine mesh. The genus differs from *Caninia* in the breadth and construction of the dissepimental zone and in that there is no breviseptal (amplexoid) phase in the development.

Genotype: *Cyathophyllum archiaci* Milne-Edwards and Haime.

Occurrence: Tournaisian and Viséan (both Lower Carboniferous) of Belgium, Britain, and France; Lower Carboniferous of Austria and possibly China.

Remarks.—According to Lang, Smith, and Thomas (1940, p. 31), "*C. archiaci* has characters intermediate between those of *Caninia* Michelin and *Palaeosmilia* Edwards & Haime, and closely resembles *Cyathophyllum flexuosum* Goldfuss" the genotype of *Campophyllum*.

CANINOPHYLLUM? READI (Merriam)

Plate 22, figures 11, 12

1942. *Campophyllum? readi* Merriam. Jour. Paleontology, vol. 16, no. 3, p. 380, pl. 57, figs. 10, 14.

External characters.—Simple, rugose corals; precise shape, external markings, calyx, and manner of increase unknown.

Transverse sections.—Holotype section, probably through a mature region (diameters 45 by 36 mm.), with 60 major septa three-quarters as long as radius; all majors dilated within tabularium, about 24 majors more dilated than the remainder; cardinal septum indicated by a short septum lying about midway in the additionally dilated series; minor septa half as long as radius, not extending within tabularium; dissepimentarium occupies one-half the radius, consists chiefly of anguloconcentric pattern but with concentric and lonsdaleoid patterns occurring without order; cardinal fossula indicated by bifurcation and apparent arching of stereoplasm of one septum on each side of short septum; young stages unknown; at stage slightly younger than type section (diameters 35 by 25 mm.) minors extend about 1 mm. into tabularium; in type section minors not quite reaching tabularium, there being 3 or 4 dissepiments intervening.

Longitudinal section.—Longitudinal section of paratype with density of 11 or 12 tabulae per cm. near their peripheries; direction of tabular arching not definitely known, some seemingly nearly flat with proximally recurved peripheries; tabulae mostly incomplete.

Remarks.—This species is known from crushed and fragmentary material and the details cannot be worked out adequately. It was originally compared with *Cyathophyllum* (*Campophyllum?*) *nevadense* Meek, which is also poorly known. Although the original description mentions the lack of a fossula, the reasons for recognizing one are outlined above. Because it does have a fossula, dilated majors, no known axial structure, and a wide dissepimentarium, the species is provisionally referred to *Caninophyllum*, even though young stages are not known.

Locality.—Common in the Coffee Creek limestone (Lower Carboniferous) of Oregon, 1¼ mi. S. 47° E. of Wade Butte, Oregon.

Material.—The holotype is Cornell Univ. No. 38697 from Merriam's locality S2. The figured paratype is probably from the same locality.

OTHER SPECIES

Campophyllum? texanum Shumard is unrecognizable, as stated by Moore and Jeffords (1941, p. 67), because the species was not figured and the types are lost. It has been mentioned by Miller (1889, p. 176), Weller (1898, p. 161), Girty (1908, p. 102), and Hill (1939, p. 104).

Of the three Devonian species, *C. nanum* Hall and Whitfield (called *Camptophyllum* [sic] by Simpson, 1900, pp. 209, 210) is the genotype of *Charactophyllum* Simpson, 1900. Specimens first identified by Whiteaves as *Chonophyllum* (*Ptychophyllum*) *ellipticum* Hall and Whitfield, but referred to the genus *Campophyllum* and subsequently named *Cyathophyllum McConnelli* by him, were assigned by Fenton and Fenton (1924, p. 34) to the genus *Tabulophyllum* F. and F., and

were considered by them to be closely related to *T. ehlersi* F. and F. "*Campophyllum mcconelli* Whiteaves" exists in the literature (Fenton and Fenton, 1924, p. 35) as a misquotation of "*Cyathophyllum McConnelli* Whiteaves," (Whiteaves, 1898, p. 422).

ACKNOWLEDGMENTS

The writer is indebted to Messrs. R. S. Bassler, Charles Butts, Carey Croneis, Wallace Hagan, C. W. Merriam, and J. M. Weller for making numerous types and other specimens available for study. Messrs. G. E. Condra and H. E. Vokes have contributed necessary information concerning stratigraphy and type material, respectively.

The peel sections made during this revision are deposited in Walker Museum, University of Chicago, Chicago, Ill.

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THE COMPOSITION OF CONODONTS

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ABSTRACT—The physical properties and chemical composition of conodonts are shown to be similar to substances such as bone, teeth, and minerals of the apatite group. The problem of conodont classification is discussed in the light of their composition. It is concluded that conodonts belong to some unit of the vertebrates (probably fish) because no other group of animals are known to have similarly shaped hard parts of such small size composed of calcium phosphate.

DETAILED information on the physical properties and chemical composition of conodonts is assembled in order to aid in a better understanding of the zoological classification of conodonts. The composition is important in this problem because these fossils have apparently undergone remarkably little change since burial. Therefore, any classification based on their size, shape, internal structure, assemblage associations, and occurrence relationships must agree with the classification based on composition.

Special thanks are due M. G. Mehl, E. B. Branson, G. A. Muilenburg, O. R. Grawe, and J. S. Cullison for their valuable suggestions. W. D. Keller aided in checking the petrographic data. O. R. Grawe and Roy W. Graves, Jr. supplied the X-ray data. W. K. Dean made the quantitative chemical analyses. The School of Mines and Metallurgy furnished laboratory facilities.

PHYSICAL PROPERTIES

COLOR: The color of conodonts ranges from dark brown to light tan or clear amber. Most of the small forms appear lighter in color. The occurrence of light-colored opaque to chalky white specimens is indicative of excessive weathering before collection or overheating during preparation in the laboratory.

HARDNESS: No accurate way to measure the hardness of these small fossils has been devised, but scratching tests show the hardness is between three and five on Moh's scale. Probably a hardness of four is near the average figure.

SPECIFIC GRAVITY: Specimens of conodonts were placed in a solution of thallium formate (sp. gr. 3.20). This liquid was diluted gradually with water and the density at each dilution was obtained by weighing a known volume of lead glass suspended in the liquid. The following data show the variation of the specific gravity of conodonts to be from 2.84 to 3.10.

	Sp. Gr. of Liquid
All conodonts float	3.10
A few platform type conodonts sink	3.06
Many platform-type conodonts, as well as those of darker colors, sink	3.03
All of the platform-type conodonts sink. Many of the bladed and barlike forms, although floating or suspended in the liquid, have their denticles pointed upward	2.96
All conodonts sink	2.84

An explanation for the phenomenon that bladed and barlike forms orient themselves with their denticles upward, when suspended in liquid of slightly higher density, may be found in the fact that such forms have air spaces inside the denticles at the apex of each growth cone. No differences in specific gravity were noted in conodonts obtained from rocks of Ordovician, Devonian, Mississippian, or Pennsylvanian ages.

FUSIBILITY: Specimens of conodonts fuse with difficulty on the edges.

INDICES OF REFRACTION: The indices for conodonts range between 1.595 and 1.612. However, most of the specimens fall between 1.600 and 1.610.

BIREFRINGENCE: The birefringence ranges from nil to weak (0.000 to 0.003). Thick pieces of conodonts under crossed nicols show only grays of the first order. Extinction shadows appear to be controlled by sheath-like layers of translucent material so arranged as to bring out the lines of the internal structure.

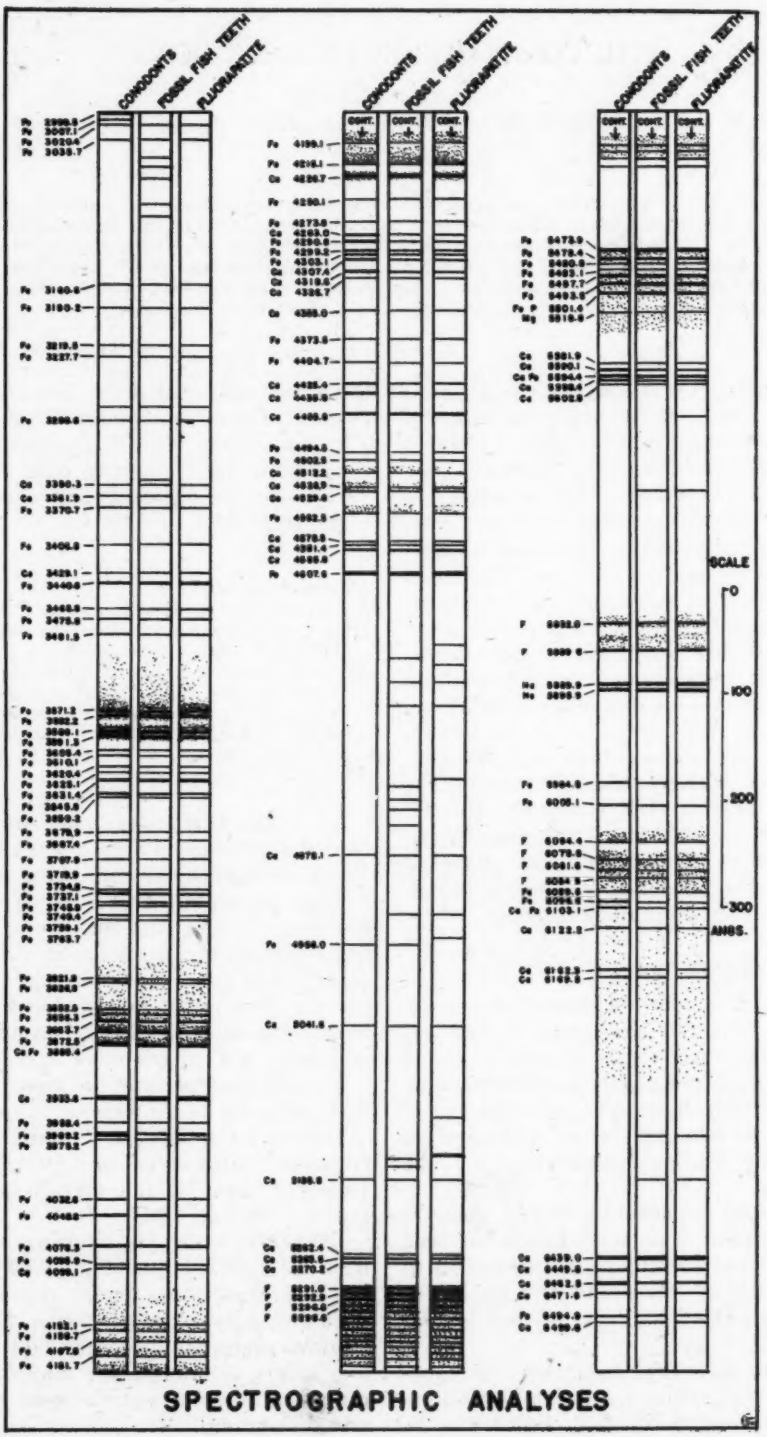
CONDONITE
FOSSIL FISH TEETH
FLUORAPATITE
SCALE
0
100
200
300
ANGS.
SPECTROGRAPHIC ANALYSES

FIG. 1

CRYSTALLINITY: X-ray diffraction patterns prepared by McConnell (Stauffer, 1938, p. 414) and Grawe and Graves (in this paper) indicate that the substance in conodonts is crystalline. However, the diffused nature of the lines on the conodont pattern as compared to the sharper lines of the fluorapatite pattern, is evidence that the crystals of mineral matter in conodonts are relatively small.

CHEMICAL COMPOSITION

QUANTITATIVE ANALYSIS: Two samples of conodonts, which were handpicked and as free from matrix as possible, were analyzed by W. K. Dean of the Department of Chemistry, School of Mines and Metallurgy, Rolla, Missouri. These samples were taken from the Quivira shale (Pennsylvanian) of Jackson County, Missouri. The data obtained by these analyses are as follows:

	Sample 1 (.03910 gm.) (Per cent)	Sample 2 (.06235 gm.) (Per cent)	Average (Per cent)
CaO	47.00	49.09	48.05
P_2O_5	34.45	35.48	34.96
Insoluble	4.05	3.87	3.96
Remainder*	14.50	11.56	13.03
Total	100.00	100.00	100.00

* Probably is CO_2, H_2O, F_2, Fe_2O_3, organic matter, etc.

Because of the difficulty of procuring large quantities of conodonts, the amounts of carbon dioxide, water, organic material, and traces of other substances were not separately determined quantitatively. The insoluble material may represent clay minerals and other matter in the matrix that adheres to the most carefully handpicked samples.

Pander (1856, p. 6) considered conodonts to be composed of calcium carbonate. Harley (1861, p. 547) corrected this misconception and stated that conodonts . . . "are composed of phosphate and carbonate of limes . . . and the color is due to sesquioxide of iron." Most subsequent workers have considered conodonts to be composed of calcium phosphate, but in a recent paper Loomis (1936, p. 663) stated, without supporting evidence, that conodonts are horny or chitinous. Stauffer and Plummer (1932, p. 21) gave Ellestad's preliminary report on the composition of conodonts as . . . "calcium phosphate ranging from 30 to 50 per cent with probably no organic matter." No other chemical analyses have been published to date.

QUALITATIVE TESTS: The presence of water and organic matter is indicated by the closed tube test in which conodonts turn dark gray and give off droplets of water. In open tube test they turn chalky white.

Conodonts are soluble in hydrochloric, nitric, and sulphuric acids. They are insoluble in acetic and citric acids.

A positive test for iron was obtained by using a paper impregnated with an alcoholic solution of *a-a'*-dipyridyl, a method outlined by Feigl (1937, p. 93).

A positive test for fluorine was obtained by using the silicic acid method described by Feigl (1937, pp. 164–165). Spot tests for sulphur, chlorine, and manganese were run but all with negative results.

SPECTROGRAPHIC DATA: The accompanying spectrogram (fig. 1) shows that conodonts are mainly calcium phosphate with traces of iron, magnesium, sodium, and fluorine. The scarcity of phosphorous lines is due to the fact that only a few lines are emitted by phosphorous in the wave-length range included on the accompanying diagrams.

X-RAY DATA: Stauffer (1938, p. 414) was first to point out the importance of the X-ray as applied to the composition of conodonts, when he discussed McConnell's X-ray powder diffraction photographs of conodonts. No data were published at that time. Later, however, McConnell[1] stated that . . . "some conodonts are probably dahllite, others francolite, and some probably lewistonite or dehrnite."

The X-ray powder diagram data on conodonts (table 3) are supplied by O. R. Grawe and Roy W. Graves, Jr., of the department of Geology, School of Mines and Metallurgy, Rolla, Missouri. The specimens for these data were obtained from the Quivira shale (Pennsylvanian) of Jackson County, Missouri.

COMPARISONS

The data on the physical and chemical properties of various minerals of the apatite group, fossil bone, and recent bone and

[1] Personal communication, March, 29, 1940.

TABLE 1.—MISCELLANEOUS PROPERTIES

	Color	Hardness	Specific Gravity	Fusibility	Indices	Birefringence	Crystallinity	Open Tube	Closed Tube	Acids		
										HCl	HNO_3	HAc
Fluorapatite[1,2,3]	Variable	5	3.17–3.23	5–5.5	ϵ 1.630–43[1,3] ϵ 1.630–51[2] ω 1.633–48 ω 1.633–55	Low	Hex. Crystalline			Sol.	Sol.	Insol.
Chlorapatite[2]	Variable	5	3.2	5	ϵ 1.664 ω 1.667	Low	Hex. crystalline			Sol.	Sol.	Insol.
Francolite[2]	Variable	4.5	3.1	Easy	ω 1.625 ± 0.002	Low	Fibrous					
Dahllite[2,3,4]	Variable	3	2.87–3.05	Infusible	ϵ 1.598–1.631[3,4] ϵ 1.619–26[3] ω 1.603–35 ω 1.623–35	Low	Hex. fibrous cryst.			Sol.	Sol.	Insol.
Dehrnite[1,4]	Variable	3–5	3.1 ±	2	ϵ 1.614–33[3] ϵ 1.59–1.63[1] ω 1.622–40 ω 1.60–1.64	Low	Hex. crystalline			Sol.	Sol.	Insol.
Lewistonite[1,3]	Variable	5	3.05		ϵ 1.613 ω 1.624	Low	Pseudo-hex. cryst.					
Hydroxyapatite[2,4]	Variable	5	3.17	Infusible	ϵ 1.629 ω 1.633	Low						
Collophane[4]	Tan or Brown	3–5	2.6–2.9	Diff. on Edges	1.57–1.63 Usually 1.59–1.61	Nil to weak	Amorphous	White	Dark gives H_2O	Sol.	Sol.	Insol.
Fossil bone[4,6]	Variable	3–5	2.60–2.94	Diff. on Edges	1.571–1.621	Nil to weak	Amorphous[6] Crystalline[5]	White	Dark gives H_2O	Sol.	Sol.	Insol.
Recent teeth[7] and bone	Variable		2.70–3.00		Bone 1.56 Dentine 1.58 Enamel 1.62	Low	Crystalline	White	Dark gives H_2O	Sol.	Sol.	Insol.
Conodonts	Tan to Brown	3–5	2.84–3.10	Diff. on Edges	1.590–1.612	Low	Crystalline	White	Dark gives H_2O	Sol.	Sol.	Insol.

[1] Dana, 1932, pp. 704, 734.
[2] Rogers and Kerr, 1942, p. 224.
[3] Larsen and Berman, 1934, pp. 83–86.
[4] Rogers, 1922, pp. 275–276
[5] Rogers, 1912, pp. 475–482
[6] Rogers, 1924, pp. 535–556
[7] Taylor and Sheard, 1929, pp. 479–493
[8] Roseberry et al., 1931, pp. 395–409

TABLE 2.—CHEMICAL ANALYSES

	CaO	P_2O_5	$\frac{P_2O_5}{CaO}$	MgO	MnO	K_2O	Na_2O	CO_2	SiO_2	SO_3	Al_2O_3	Fe_2O_3	F_2	Cl_2	H_2O	Insol.	Others	Total
Fluorapatite[1]	55.16	41.3	.748		0.12			0.5			0.24	0.63	3.67	0.09	0.01		0.42	102.14
Fluorapatite[3]	52.4	40.3	.769	0.46				1.51	3.08			0.6	3.26	0.16			1.95	103.72
Chlorapatite[2]	52.97	40.5	.764	0.29		0.1	0.22		1.16		0.98	0.18	0.17	4.13			0.48	101.18
Francolite[1]	54.88	37.71	.687					3.36					4.11		1.18		0.24	101.79
Dahllite[1]	53.65	38.4	.715					5.3			0.57		Tr.		2.1			100.02
Dehrnite[1]	50.88	37.92	.745			1.2	7.11	1.49			Tr.				1.68		0.12	99.6
Lewistonite[1]	46.78	37.92	.810			1.36	4.34				2.53				7.69			100.62
Hydroxy-apatite[1]	55.47	42.19	.760		0.06										1.73		0.6	100.05
Hydroxy-apatite[2]	49.99	38.68	.773	0.11			1.01	0.12	0.54			0.13					8.56	99.14
Steamed Bone[2]	50.97	38.47	.754	0.67			0.69	1.5				0.13					8.3	100.72
High-grade Tennessee blue phosphate ore[4]	47.24	35.04	.741					2.27	2.96		0.68	1.56	1.96		3.82		4.97	100.5
Collophane[4]	50.97	36.35	.713	0.22				1.72		2.98	0.76		0.4		1.05	1.82		99.04
Human bone[5]	51.31	36.65	.714	0.77		0.32	1.04								2.46		7.4	99.95
Ox bone[5]	51.28	37.46	.730	1.05		0.18	1.09								2.33		7.0	100.4
Ox teeth[5]	50.7	38.88	.760	1.52		0.2	1.16								2.21		5.0	99.67
Ox teeth enamel[5]	51.98	39.7	.763	0.53		0.2	1.1								1.18	0.2	5.0	99.69
Fossil bone[6]	48.51	37.79	.779	Tr.				4.73		0.03	0.98	2.0	0.93		3.47			99.22
				Tr.			Tr.	Pres.			Tr.	Pres.	Pres.		Pres.	3.96		
Conodonts	48.05	34.96	.727	13.03														100.00

[1] McConnell, 1938, p. 6.
[2] Hendricks et al., 1931, p. 1416.
[3] Smith and Whitlatch, 1940, p. 303.
[4] Rogers, 1922, p. 273.
[5] Gabriel, 1894, p. 281.
[6] Rogers, 1924, p. 539.

TABLE 3.—X-RAY ANALYSES

No.	Fluor-apatite[1]		Fluor-apatite[2]		Chlor-apatite[2]		Francolite[1]		Dahllite[1]		Dahllite[2]		Dehrnite[1]		Hydroxy-apatite[1]		Fossil bone[2]		Tooth enamel[2]		Recent bone[2]		Conodonts	
	D/N	I	D/N	I	D/N	I	D/N	I	D/N	I	D/N	I	D/N	I	D/N	I	D/N	I	D/N	I	D/N	I	D/N	I
1.			3.85	0.2	3.81	0.5					3.75	2.0					3.85	0.5	3.85	0.5				
2.	3.43	2.0	3.40	1.5	3.35	2.5	3.43	2.0	3.43	2.0	3.35	1.5	3.43	1.0	3.44	1.0	3.35	2.5	3.35	2.5	3.35	2.0	3.33	2.0
3.			3.15	5.0	3.15	1.5	3.15	0.5					3.16	0.5	3.16	0.5								
4.	3.06	3.0	3.02	5.0	3.05	5.0	3.04	2.0	3.07	3.0	3.02	1.5	3.04	3.0	3.06	2.0	3.02	1.0	3.02	1.0	3.02	0.5		
5.	2.97	5.0					2.59	0.5	2.99	1.0			2.96	0.5	2.98	0.5							2.97	2.0
6.	2.88	5.0					2.88	0.5																
7.	2.79	10.0							2.81	10.0					2.79	10.0								
8.	2.76	4.0	2.72	10.0	2.72	10.0	2.76	10.0	2.77	3.0	2.72	10.0	2.76	10.0	2.77	4.0	2.72	10.0	2.72	10.0	2.72	10.0	2.72	10.0
9.	2.70	6.0					2.68	7.0	2.71	6.0			2.68	6.0	2.70	6.0								
10.	2.61	3.0	2.60	2.0	2.60	1.5	2.61	4.0	2.62	1.0	2.60	1.0	2.61	3.0	2.62	2.0	2.60	2.0	2.60	2.0			2.61	2.0
11.	2.51	0.5	2.51	0.2			2.50	0.5	2.52	0.5			2.50	0.5									2.55	0.5
12.	2.47	0.5					2.46	0.5	2.49	0.5			2.46	0.5									2.42	0.5
13.	2.28	0.5					2.27	1.0					2.28	0.5										
14.	2.24	2.0	2.25	2.5	2.26	4.0	2.23	3.0	2.25	4.0	2.24	2.0	2.23	4.0	2.24	2.0	2.25	1.0	2.25	1.0	2.25	2.5	2.19	4.0
15.	2.13	1.0	2.13	2.0	2.13	1.5	2.12	2.0	2.15	2.0	2.12	0.5	2.12	2.0	2.13	1.0	2.13	0.5	2.13	0.5				
16.	2.05	1.0	2.05	2.0			2.06	1.0					2.05	0.5	2.05	5.0	2.05	2.5	2.05	2.5			2.08	2.0
17.	2.02	0.5			2.02	2.0	2.02	1.0	2.03	0.5			2.02	0.5	2.02	0.5								
18.	2.00	0.5					1.99	1.0	1.99	0.5													1.99	0.5
19.							1.96	5.0																
20.	1.93	3.0	1.93	4.0	1.93	5.0	1.92	3.0	1.94	4.0	1.93	0.5	1.92	6.0	1.93	3.0	1.93	1.0	1.93	1.0	1.93	1.0		
21.	1.88	1.0	1.88	2.0	1.88	2.0	1.87	1.0	1.88	1.0	1.87	2.5	1.87	2.0	1.88	1.0	1.88	0.5	1.89	2.0			1.89	1.0
22.	1.83	6.0	1.83	4.0	1.82	5.0	1.83	3.0	1.84	2.0	1.83	1.5	1.83	6.0	1.83	5.0	1.83	2.0	1.83	4.0	1.83	2.0	1.84	4.0
23.	1.79	3.0	1.79	0.5			1.78	2.0	1.80	1.0			1.78	2.0	1.79	2.0							1.79	2.0
24.	1.76	3.0	1.75	0.5	1.75	1.0	1.76	2.0	1.77	1.0			1.75	2.0	1.76	2.0							1.76	2.0
25.	1.74	3.0					1.74	2.0	1.75	1.0			1.74	2.0	1.74	2.0							1.73	2.0
26.	1.72	3.0	1.71	1.5	1.71	0.5	1.72	2.0	1.72	1.0	1.71	2.5	1.71	2.0	1.72	2.0	1.71	1.5	1.71	2.0	1.71	2.0	1.71	2.0
27.			1.64	1.0	1.64	0.5					1.62	0.5							1.64	1.0			1.68	0.5
28.			1.53	1.5	1.52	2.0					1.51	0.5					1.53	1.5	1.53	0.5			1.60	1.0
29.			1.49	1.0	1.49	4.0					1.49	0.2					1.49	0.2	1.49	0.2			1.49	0.2
30			1.44	1.5	1.44	1.0					1.44	0.2					1.44	1.5	1.44	2.0	1.43	1.0	1.44	1.0
31.																							1.42	0.2
32.																							1.40	0.2
33.			1.34	0.2	1.32	1.5					1.33	0.1							1.34	0.2			1.32	0.2
34.			1.30	1.0							1.30	0.2					1.30	0.5	1.30	0.5	1.30	0.2	1.29	0.5
35.			1.27	1.0	1.27	3.5					1.27	0.5					1.27	0.5	1.27	0.2			1.26	0.2
36.			1.25	0.5							1.25	0.2												
37.			1.23	0.5	1.23	1.0					1.23	0.2					1.23	0.5					1.22	0.5
38.			1.21	0.5							1.20	0.5							1.21	1.0	1.21	0.5	1.20	0.5
39.			1.14	0.5	1.14	0.2					1.14	0.2					1.14	0.5	1.14	0.5	1.14	0.5	1.13	0.5
40.			1.10	0.5	1.10	0.3					1.11	0.5					1.10	0.5	1.10	0.5	1.10	0.5	1.09	0.5
41.			1.09	0.5							1.09	0.5											1.08	0.5

[1] McConnell 1938, p. 5. [2] Roseberry et al. 1931, pp. 395–409.

teeth are collected on the accompanying charts (fig. 1, tables 1–3) for comparison with conodonts.

It is easily seen that many of the physical properties are the same for each of the substances under consideration. On the other hand, some of the properties differ markedly. For example, the hardness of conodonts more nearly agrees with the hardness of dahllite, francolite, dehrnite, collophane, or fossil bone. The specific gravity of conodonts is close to all of the substances except fluorapatite, chlorapatite, and hydroxyapatite. The refractive indices of conodonts approach those of dahllite, dehrnite, collophane, and bone. The fusibility of conodonts is like that of collophane and fossil bone.

Contrary to Rogers' (1924, pp. 535–555) statement that the mineral matter in fossil bone, modern bone, and collophane are amorphous, X-ray analyses by DeJong (1926, pp. 870–872), Taylor and Sheard (1929, pp. 479–493), Roseberry, Hastings, and Morse (1931, pp. 395–405), and Hendricks, Hill, Jacob, and Jefferson (1931, pp. 1413–1418) have shown these substances to be crystalline. However, Rogers and Kerr (1942, p. 115) have recently insisted these materials are amorphous but admit they have directional properties sensitive to the short wavelengths of X-rays.

The chemical composition of conodonts is similar to that of dahllite, dehrnite, collophane, and the mineral matter in fossil and recent bones and teeth. The greatest similarity in composition is seen in the analyses of conodonts and the high grade blue phosphate ore of Tennessee. Smith and Whitlatch (1940, pp. 302–303) have studied these ores in thin section and conclude that they are composed of dahllite, collophane, fragments of conodonts (which are said to be clear amber collophane), and foreign material such as clay, quartz grains, and organic material.

Comparison of spectrograms shows that lines given off by conodonts are similar to those emitted by fossil fish teeth and fluorapatite.

The X-ray diffraction pattern data on conodonts are very close to those published by Roseberry, Hastings, and Morse (1931, pp. 395–405) for fluorapatite, chlorapatite, dahllite, and bone. The data presented by McConnell (1938, pp. 1–19) on the apatite minerals do not entirely agree with those of Roseberry, Hastings, and Morse. This disagreement may be due to differences in observation technique or to differences in source material.

Exhaustive studies by Gabriel (1894, pp. 257–303), Gassmann (1910, pp. 161–170), DeJong (1926, pp. 870–872), Kramer and Shear (1928, pp. 105–147), Taylor and Sheard (1929, pp. 479–493), Roseberry, Hastings, and Morse (1931, pp. 395–405), and Hendricks, Hill, Jacob, and Jefferson (1931, pp. 1413–1418) on the chemical, spectrographic, and X-ray analyses of bone have indicated that the mineral matter in bone and teeth is a crystalline substance like the apatite minerals.

Taylor and Sheard (1929, pp. 479–493) have shown that the less organic material present in the bone tissue the higher the refractive index. Therefore, the less organic material in the bone or tooth the nearer it approaches the indices of apatite. Dental enamel has an index of 1.62, dentine 1.58, and limb bones 1.56. Of course, all gradations exist between these values.

Hendricks, Hill, Jacob, and Jefferson (1931, pp. 1413–1418) have shown that less than 2 per cent calcium carbonate exists, as such, in the mineral matter of bones. They sight evidence that the mineral matter in bone is carbonate apatite. McConnell and Gruner (1940, pp. 157–167) independently arrived at the same conclusions but go further to state that the substance of teeth and bones should properly be called carbonate hydroxyapatite or dahllite.

It is apparent from the foregoing discussion that the composition of conodonts is the same as the mineral matter in fossil and recent bone and teeth. Furthermore, this substance is similar to the minerals of the apatite group.

COMPOSITION AND CLASSIFICATION

Conodonts have been considered as molluscan radulae by Loomis (1936, p. 663) and Pilsbry (1937, p. 101) on the basis of similarity in shape and size. However, the known molluscan radulae are not composed of calcium phosphate. Harley (1861, pp. 542, 553) suggested conodonts were spines from animals like *Limulus* and *Squilla*.

Likewise, Rohon and Zittell (1886, pp. 108–136) suggested conodonts were broken spines of crustaceans. However, the known arthropod remains are chitinous, horny, siliceous, or calcareous and not composed of calcium phosphate.

Conodonts have been assigned to the worms mainly on the basis of shape and size. This literature is reviewed thoroughly by Stauffer and Plummer (1932, pp. 13–20) and Scott (1934, pp. 449–450). Scott, however, considered them paired jaw parts in assemblages. He emphasized their similarity in this respect to worm mandibles. DuBois (1943, pp. 155–159) considered conodonts as Annelida chiefly on the basis of assemblages. On the other hand he has given some zoological evidence that in the geologic past worms may have secreted mandibles composed of calcium phosphate. However, the known worm mandibles, either fossil (scolecodonts) or modern are composed of chitinous, horny, or siliceous material and not calcium phosphate. Some groups of fish are known to have several kinds of teeth in the same individual. Therefore, fish are no different than worms when the subject of assemblages is considered.

Branson and Mehl (1933, p. 5) have found material with bone-like structure commonly fixed to the attachment scars of conodonts. Cullison (1938, pp. 219–228) described and figured a complete mandible set with conodonts (*Archeognathus primus* Cullison) from the Dutchtown (Ordovician) formation of Missouri. Demanet (1938, pp. 215–219) discovered conodonts, presumably in place, on the gill arches of a Carboniferous fish in the British Museum. Demanet's drawings, however, give no definite proof that the conodonts were not associated with these fish remains purely by chance in the processes of burial.

Pander (1856, pp. 1–91) illustrated the fibrous and laminated internal structure of conodonts and compared them to fish in this respect. Hass (1941, pp. 71–81) has further illustrated these same features but makes no commitments as to classification. These studies of internal structures show that conodonts are not differentiated into dentine and enamel, a feature so characteristic of vertebrate teeth above the level of fish.

The fact that conodonts occur in rocks as old as Ordovician is evidence that they belong to some of the fishes or lower vertebrates because higher forms are not known to have been developed at that particular geologic time.

The associated fossils help little in solving the problem of classification because conodonts are associated in the same stratigraphic units with fish teeth, fish jaws, fish scales, gastropods, cephalopods, pelecypods, crustacea, scolecodonts, worm castings, and worm borings.

It is evident that conodonts may be considered as vertebrates on the basis of composition, size, shape, associated bone material, and assemblage associations. They are further restricted to the fish or lower vertebrates on the basis of internal structure and stratigraphic occurrence. To consider conodonts as belonging to any other group is to disagree with the evidence afforded by the composition.

CONCLUSIONS

1. The composition of conodonts is the same as the mineral matter in fossil and modern vertebrate hard parts. This mineral matter is similar to the minerals of the apatite group.

2. Conodonts may be classified as fish or lower vertebrates on the basis of their composition, size, shape, assemblage associations, internal structure, associated bone material and jaw parts, and stratigraphic occurrence.

3. The assignment of conodonts to other zoological groups is challenged because these other groups do not have hard parts of similar size and shape that are composed of calcium phosphate.

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JOURNAL OF PALEONTOLOGY, VOL. 18, NO. 2, PP. 141–147, PLS. 23–24, 1 TEXT FIG., MARCH 1944

PERMIAN AND PENNSYLVANIAN FRESH-WATER OSTRACODES

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ABSTRACT.—Nine species of ostracodes from fresh-water limestones of Permian and Pennsylvanian age are described. Shell characters are given for three previously established genera and one new genus, *Gutschickia*. They are oriented on the basis of the position of the muscle scar, which is situated slightly anteroventrally of the midpoint.

FRESH-WATER ostracodes are among the rarest of Paleozoic fossils. They are rare because of the environment in which they lived, although they were probably much more abundant in the ponds and lakes of the Paleozoic than the few fossil remains would indicate. This paper records the occurrence of one species from the Cohn cyclothem of the Pennsylvanian of Illinois and a Permian collection from the Nineveh limestone of Pennsylvania and West Virginia.

Fresh-water limestones are occasionally found throughout the Pennsylvanian section in Illinois. They range from highly argillaceous to fairly pure lithographic limestone. Any individual bed is local in extent, often lenslike, nodular and thin. Such limestones are mostly unfossiliferous but they locally contain ostracodes in considerable numbers. *Spirorbis* is often associated with the ostracodes.

Only a few references have been made to the occurrence of Paleozoic fresh-water ostracodes in America. In a report by Holland (1934) several species were described from the Nineveh limestone, Dunkard series, of Permian age. His material was collected in Pennsylvania and West Virginia and described under the new generic name *Whipplella*. This genus was assigned to the Leperditellidae and compared to the genus *Paraparchites*. *Whipplella*, however, should not be placed in the same family as the straight-hinged marine ostracode *Paraparchites*. Some of the species referred to *Whipplella* can hardly be distinguished from *Cypridopsis* and certainly should be assigned to the family *Cypridae*. The convexity of the dorsum, the simple method of hingement, the obtuse cardinal angles, and the pitted surface readily distinguish it from the Leperditellidae. The same features point to its Cypridae affinities.

More or less the same criteria are used for the identification of fresh-water and marine ostracodes. Among the more important features are: 1, method of hingement, whether by tooth and socket, overlap, or elastic band; 2, convex or straight dorsum; 3, general outline; 4, amount or method (but not direction) of overlap; 5, muscle scars; and 6, ornamentation. There is little, if any, value in the direction of overlap for generic determination. Reversal in overlap among different species of the same genus, or genera of the same family, is the rule rather than the exception. In *Cypridopsis vidua* (O. F. Müller) the left valve overlaps the right, but in *C. elongata* (Kaufmann) the right overlaps the left and many other examples could be cited. The most important of all characters for orientation is the position of the adductor muscle scars; they are situated slightly anterior of midcarapace.

Fresh-water ostracodes obtained from the Cohn limestone of the Pennsylvanian have been compared with the Permian material collected by Holland. At least a hundred fossil specimens have been studied. They are very similar to *Whipplella*.

Fresh-water ostracodes give considerable information concerning the environmental conditions of deposition. The presence of *Candona*, *Cypridopsis*, and *Whipplella* in the Nineveh limestone suggest that the lakes in which they lived were shallow, but probably of the permanent variety. The floors of the lakes were certainly covered in part with mud, decayed vegetable matter, and algae. The temperature of the water was similar to that found in lakes in the vernal period in eastern United States today.

The presence of *Whipplella*, an ostracode very closely related to *Cypridopsis*, in the fresh-water limestones of the Pennsylvanian suggests that the lakes and ponds in which they lived were very shallow, possibly as few as five or ten feet in depth. Other conditions were similar to those mentioned above.

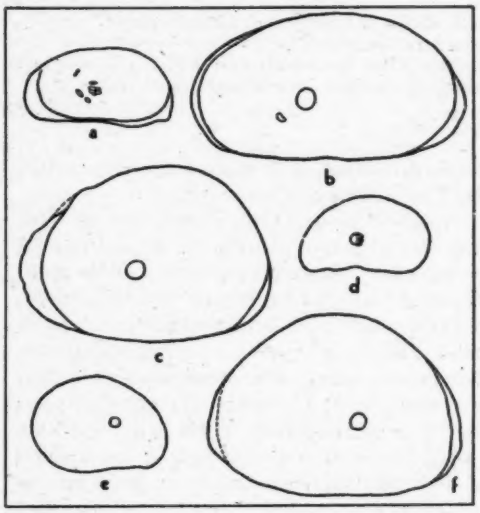

FIG. *1*—Muscle scars of ostracodes.

a. *Candona sigmoides* Sharpe. Outside view of left valve of living species from Illinois. (After Hoff)
b. *Candona magnitata* (Holland). Outside view of left valve. Permian
c. *Gutschickia ninevehensis* (Holland). Outside view of left valve. Permian
d. *Whipplella cuneiformis* Holland. Outside view of left valve. Permian
e. *Whipplella cuneiformis* Holland. Outside view of right valve. Permian
f. *Gutschickia deltoidea* (Holland). Outside view of right valve. Permian

NOTE.—Each circular muscle scar in the fossil shells may represent a rosette of several closely spaced small scars, but details cannot be observed. Scars and internal flanges can be observed best when the shell is moistened. All figures ×43.

These Carboniferous fresh-water limestones apparently owe their origin to the presence of algae that lived in very shallow moderately warm water. No algal structure has actually been observed, but the presence of ostracodes that lived primarily upon algae, and the thin, nodular and discontinuous nature of many Pennsylvanian limestones point to such an origin.

Special thanks are due to Dr. E. R. Eller, Carnegie Museum, for making available to me the holotype and paratype material from the Nineveh formation. I am indebted to Mr. John Lester, Geologist, Shell Oil Company who collected the Illinois material. Dr. C. Clayton Hoff, Department of Zoology, University of Illinois, furnished me with specimens of fresh-water ostracodes collected in the state of Illinois and his collection has proved invaluable in my study of fossil fresh-water ostracodes.

SYSTEMATIC DESCRIPTIONS

Order OSTRACODA Latreille
Family CYPRIDAE Baird
Genus WHIPPLELLA Holland, 1934

Carapace ovate, dorsum convex; venter gently concave to straight; valves unequal, one overlapping the other around free margin; hinge short, represented by knife-edged groove, one valve raised very slightly above other along hinge; surface minutely to strongly pitted; posterior end thickest; muscle scar rounded, anteroventral of midpoint.

Genotype: *Whipplella cuneiformis* Holland.

Whipplella is very closely related to *Cypridopsis*. The only external difference is the presence of pronounced overlap around the free margin of *Whipplella*. Hingement and shape are about the same. There is no evidence of an internal marginal flange. It is also similar to *Cypridopsella*. The presence of a well-preserved muscle scar leaves no doubt as to the orientation of this genus. The thickest end is posterior and the right valve strongly overlaps the left all around the free margin in all species and specimens studied. The hinge is very short, about one-third of shell length, and is situated in a medial position along the dorsum. When the right valve is the larger and overlaps the left around the free margin the left valve is raised slightly above the right along the hinge. There are no known cases of reversal of overlap in *Whipplella*.

WHIPPLELLA CUNEIFORMIS Holland
Plate 24, figures 18–20

Whipplella cuneiformis Holland, 1934, Carnegie Museum Annals, vol. 22, p. 344, pl. 25, figs. 5a–c.

Carapace ovate, dorsum arched, venter straight to gently concave; greatest height medial to slightly posterior of median point; outline strongly cuneate in dorsal view, greatest thickness in posterior third; hinge short, occupying medial third of dorsum, narrow groove along hinge between valves; overlap of left valve by larger right begins where hingement stops, continues around free margin, greatest overlap along anterior end and anterior half of venter; posterior half of carapace covered with closely spaced rounded pits, becoming faint and finally disappearing in anterior half.

Holotype: Carnegie Museum no. 6493.

WHIPPLELLA DEPRESSA Holland
Plate 24, figures 21–23

Whipplella depressa Holland, 1934, Carnegie Museum Annals, vol. 22, p. 345, pl. 23, figs. 7a–c.

Carapace ovate in lateral view, ends evenly rounded; greatest length median, greatest height slightly posterior of median; dorsum broadly, evenly convex, venter straight to gently concave; valves unequal, larger right valve strongly overlaps left around free margin; anterior end cuneate, posterior end rounded in dorsal view; greatest thickness in posterior half; hinge occupies medial third of dorsum, sharply impressed forming narrow slitlike channel between dorsal margins of valves, overlap begins where hingement stops; valves covered with elongate coarse pits that tend to be arranged in rows paralleling outline of carapace.

This species can be distinguished from *W. cuneiformis* by its smaller size, elongate shape, and regular pattern of large pits.

Holotype, Carnegie Museum no. 6491.

WHIPPLELLA CARBONARIA Scott, n. sp.
Plate 24, figures 3–5

Carapace elongate-ovate, posterior extremity more obtusely rounded, anterior end cuneate; dorsum broadly convex, venter gently ovate in dorsal view; greatest thickness slightly posterior of middle, equal to or exceeding greatest height; right valve largest, overlapping left around free margin, greatest overlap along median half of venter; hinge occupies about one-third of dorsal margin, impressed into very narrow slit-like depression; surface distinctly sculptured with rather coarse rounded to slightly elongate pits; carapace densely covered with minute brown specks. Length 0.82 mm., height 0.45 mm., thickness 0.47 mm. Internal characteristics unknown.

Holotype, University of Illinois no. x-1305.

Paratype, University of Illinois no. x-1312 Paratypes also in Carnegie Museum. From fresh-water limestone of the Cohn cyclothem, McLeansboro group, Pennsylvanian; Webbs Ferry, White Co., Illinois.

The brown specks may possibly represent original coloring matter in the shell. Though generally disseminated over the carapace they have a tendency to be more thickly concentrated around the median area, dorsally and ventrally. There are no similar brown specks or discolorations in the light gray to cream-colored matrix surrounding the valves. Furthermore, the calcite filling of the valves is colorless so that in all cases the brown specks are limited to the shell zone and are present in all the specimens of my collection. These conditions in conjunction with the fact that the valves of some modern species of Cypridae are often similarly colored suggest that the brown specks in *W. carbonaria* may be primary.

In some specimens the pits are arranged in rows which parallel the margin of the valves. The pits are generally best developed in the dorsal half of the carapace.

Genus CYPRIDOPSIS Brady, 1867

Valves elliptical to strongly ovate in lateral view; dorsum broadly to sharply arched, venter straight to gently sinuate; valves subequal, right valve generally larger, greatest overlap in medial portion of venter; hingement simple, no tooth and socket arrangement; hinge short, about one-third length of shell, valves separated along hinge by narrow knife-edged slit; valves smooth to pitted; muscle scars slightly anteroventral of median point, each scar slightly elongated.

This genus is here interpreted as including the forms originally described by Brady and

not in the restricted sense of G. O. Sars (1922). Paleontologists cannot hope to distinguish between the fossil shells of *Cypridopsis* and *Pionocypris;* in fact, there is not uniformity of opinion on the classification of modern species within the two genera. No adequate description of the valves of any living species of this genus has ever been given. *C. vidua*, the most common and widespread member of the genus, is hereby chosen for descriptive purposes.

CYPRIDOPSIS VIDUA (O. F. Müller)
Plate 24, figures 1–2, 9–11

Cypris vidua O. F. Müller, 1776, Zool. Danicae Prodromus. Havniae.
Cypridopsis vidua (O. F. Müller) Brady, G. S., 1867. A synopsis of the recent British Ostracoda. vol. 12, pp. 110–130.

Exterior: Carapace tumid, oval to somewhat elliptical in outline, extremities obtusely rounded; dorsum broadly to strongly convex, venter relatively straight to gently concave. Greatest height median; oblong-ovate to elliptical in dorsal view, posterior end broadly rounded, anterior end rounded to cuneate; greatest thickness median to posterior. Valves subequal, larger gently overlapping smaller, overlap begins along dorsal margin about one-third of distance from anterior end, continues around free margin; free margin of overlapping valve thinned to fit slightly incurved margin of opposite valve; hinge occupies about one-third to one-half of dorsum extending from point slightly anterior of midpoint toward posterior end, narrow slit-like depression along hinge; surface sculptured with closely set pits, often covered with minute hairs; carapace colorless to varicolored, generally some shade of yellow, brown or green, specks arranged in patches, bands, or disseminated.

Interior: One valve marked by narrow inward-sloping flange, part or all of flange on opposite valve possesses very narrow ridge fitting along inner free margin of smaller valve; muscle scars slightly anteroventral, arranged with group of four close to midcarapace and group of two more anteroventral.

Ecology: *Cypridopsis* is one of the more common modern fresh-water ostracodes. *C. vidua* (O. F. Müller) has been called the most abundant fresh-water ostracode in North America. It is also widely distributed in Europe and central Asia and a closely related species, *C. flavescens* Sars, is common in South America.

This species is most commonly found in shallow pond or lake water of the temperate and tropical zones. Food consists mostly of algae, and therefore individuals are most abundant where those plants grow.

CYPRIDOPSIS OVATA (Holland)
Plate 24, figures 15–17

Whipplella ovata Holland, 1934. Carnegie Museum Ann., vol. 22, p. 348, pl. 25, figs. 4a–c.

The orientation of this species is the reverse of that given by Holland as shown by the position of the muscle scar. The thickest end is posterior and the right valve overlaps the left. This species is referred to *Cypridopsis* instead of *Whipplella* because of its smooth surface, gently concave venter, and small amount of overlap. In dorsal view the hinge and contact of the two valves is gently concave toward the left valve. Details of the muscle scar are not clear but when the shell is moistened three small scars can be seen in the posterior half of the primary scar.

Holotype, Carnegie Museum no. 6485.

CYPRIDOPSIS PARVULA (Holland)
Plate 24, figures 12–14

Whipplella parvula Holland, 1934, Carnegie Museum Annals, vol. 22, p. 347, pl. 25, figs. 6a–c.

C. parvula is very similar in size and outline to the modern *C. vidua*. The muscle scars show faintly on both valves of the

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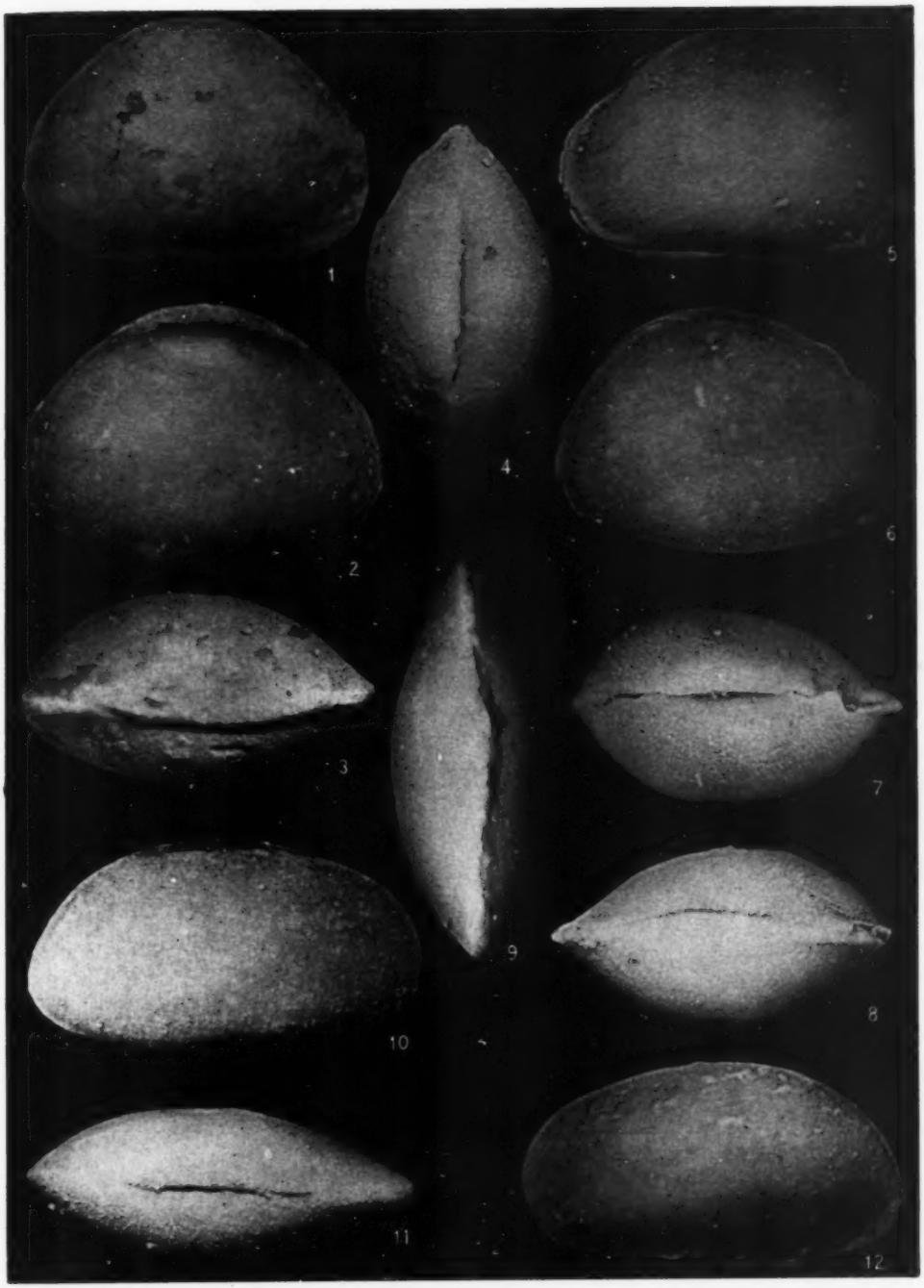
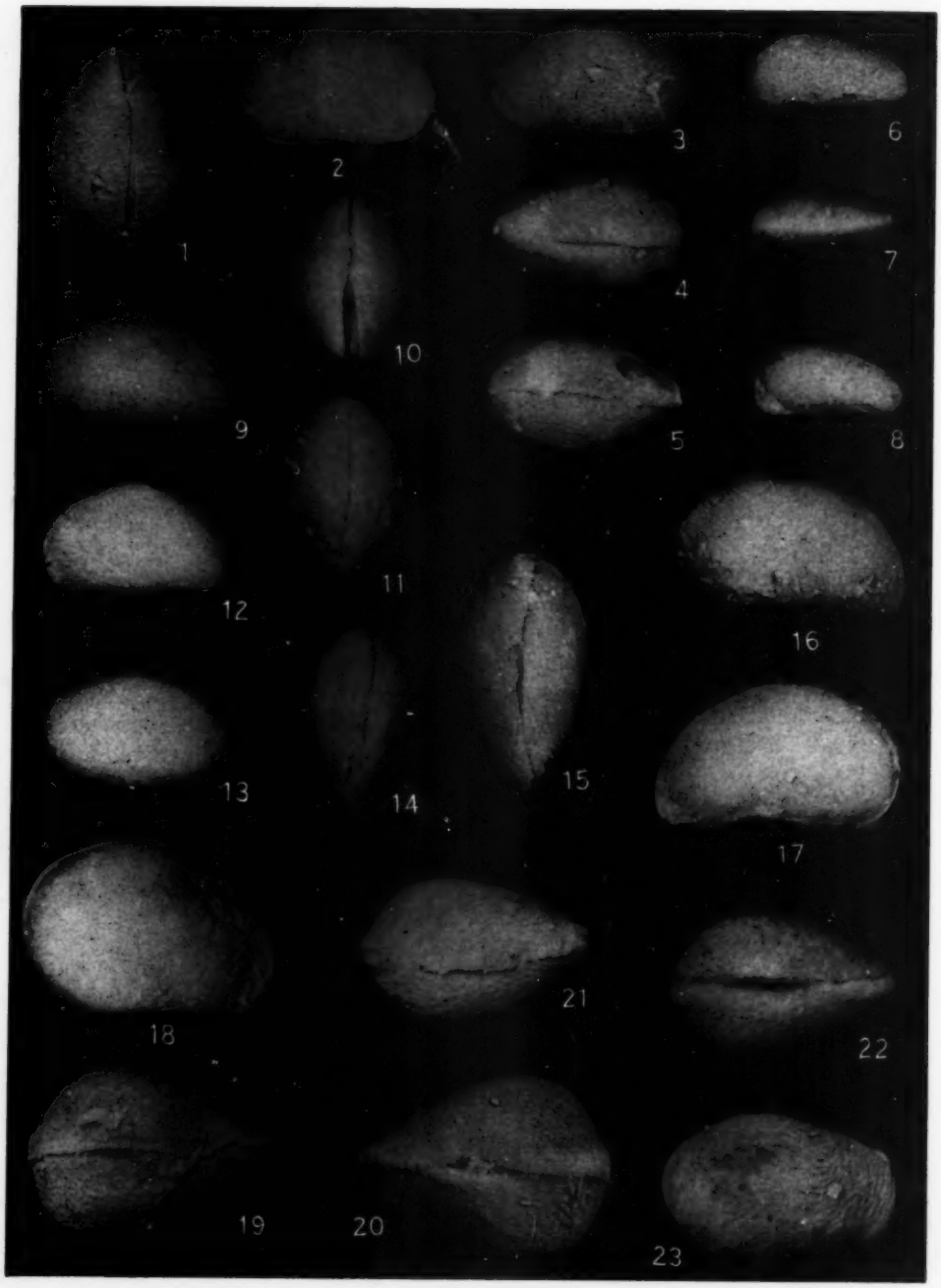
EXPLANATION PLATE 23
All figures ×-32

FIGS. *1–4—Gutschickia deltoidea* (Holland). *1*, Left valve. *2*, right valve. *3*, venter, posterior end to left. *4*, dorsum. (p. 146)
5–8—Gutschickia ninevehensis (Holland). *5*, Left valve. *6*, Right valve. *7*, Dorsum, posterior end to left. *8*, Venter. (p. 146)
9–12—Candona magnitata (Holland). *9*, Venter, posterior end down. *10*, Right valve. *11*, Dorsum, posterior end to left. *12*, Left valve. (p. 145)



Scott, Fresh-water Ostracodes



Scott, Fresh-water Ostracodes

paratype (Carnegie Museum no. 6490) but do not show on the holotype. Using the muscle scar as a basis of orientation the thickest end is posterior and the right valve overlaps the left around the free margin.

Like *C. ovata*, *C. parvula* is removed from *Whipplella* because it has a smooth surface, a narrower groove along the hinge, and less overlap around the free margins. The overlap around the ends of *Whipplella* is especially strong, whereas, in *Cypridopsis* it is slight.

Holotype, Carnegie Museum no. 6489.

Genus CANDONA Baird, 1845

Valves elongate-ovoid to reniform, subequal; dorsum broadly convex to straight, venter gently to strongly concave; anterior end more rounded, posterodorsal edge usually truncated; greatest height in posterior half; dorsal view elongate elliptical; surface smooth to punctate; interior marked by a flange adjacent to and continuing around free margin, widest at anterior end, narrow to absent along middle portion of venter; muscle scar pattern variable, situated slightly anterior of median point, generally consisting of one closely spaced group of four or five scars with single scar directly above, other scars sometimes present in area anterior to main group; left valve generally raised slightly above right along dorsum; right overlaps left ventrally, valves subequal around ends.

The genus *Candona* is represented by more than 150 living species. They have been divided into seven groups, each based on the number of position of setae. The general shell characteristics are more constant than the internal features. The greatest shell variation seems to be the relationship of height to length. In some species the height is less than one half the length but in others much greater than one half. The valves of many modern species are set with hairs that protrude from small papillae. Hairs are also common around the posterior and anterior ends.

Ecology: *Candona* is restricted to bodies of fresh water. Species may be obtained from temporary and permanent lakes and streams of all sizes, even from water in crayfish burrows. They reach their greatest development in small vernal ponds and lakes. The largest number of individuals is to be found between March and August. They are all creeping and burrowing forms preferring quiet water, though some have adapted themselves to swift currents. Most species prefer a muddy bottom covered with grass or algae.

CANDONA MAGNITATA (Holland)

Plate 23, figures 9–12

Whipplella magnitata Holland, 1934, Carnegie Museum Annals, vol. 22, p. 346, figs. 2a–c, pl. 25.

Carapace large, elongate-ovoid; dorsum broadly arched, venter broadly arched to straight; anterior end smoothly rounded, posterior end slightly pointed below median line; right valve overlaps left along median half of venter; left valve raised slightly above right along hinge, no overlap around ends; elliptical in dorsal view, ends acumi-

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EXPLANATION PLATE 24

All figures × 43

FIGS. *1–2, 9–11—Cypridopsis vidua* (O. F. Müller). *1*, Dorsal view, antennae mark anterior end. *2*, Right valve, antennae protruding. *9*, Left valve of smaller specimen. *10*, Ventral view, valves partially opened. *11*, Dorsal view. Minute pits covering carapace do not show except on posterior end of figure *1*. Recent, from ponds and lakes in Illinois. (p. 144)

3–5—Whipplella carbonaria Scott n. sp. *3*, Left valve. *4*, Dorsal view, anterior end to left. *5*, Ventral view. Cohn cyclothem, upper Pennsylvanian. (p. 143)

6–8—Darwinula hollandi Scott n. sp. *6*, Right valve of holotype, C. M. no. 24, 625. *7*, Dorsal view. *8*, Right valve; paratype, Univ. of Illinois no. X-1297. Permian. (p. 146)

12–14—Cypridopsis parvula (Holland). *12*, Left valve. *13*, Right valve. *14*, Dorsal view. Permian. (p. 144)

15–17—Cypridopsis ovata (Holland). *15*, Dorsal view. *16*, Right valve. *17*, Left valve. Permian. (p. 144)

18–20—Whipplella cuneiformis Holland. *18*, Right valve. *19*, Ventral view. *20*, Dorsal view. Permian. (p. 143)

21–23—Whipplella depressa Holland. *21*, Ventral view. *22*, Dorsal view. *23*, Right valve. Permian. (p. 143)

nate; hinge occupies median half of dorsum; surface smooth; narrow inner flange shows around anterior and posterior ends; circular muscle scar slightly anteroventral of median point.

Holotype, Carnegie Museum no. 6487.

Genus GUTSCHICKIA Scott, n. gen.

Carapace large, ovate; dorsum strongly convex; venter straight to gently convex; ends rounded; greatest height medial to slightly posterior of middle; greatest thickness medial to slightly posterior of median; ovate to elliptical in dorsal view; hinge one-half to one-third length of shell, situated in midportion of carapace, slight impression along hinge forms knife-edged groove; valves strongly unequal, right overlaps left along medial portion of venter, left valve raised sharply above right along hinge, no overlap around ends; surface finely pitted to smooth; muscle scar rounded; slightly anteroventral of midpoint; inner marginal flange around anterior and posterior ends.

Genotype, *Gutschickia ninevehensis* (Holland).

The lack of overlap around the ends, the presence of a distinct inner marginal flange, the raising of one valve along the hinge and overlap by the opposite valve along the venter, and the greater height of *Gutschickia* readily distinguishes it from *Whipplella*. The same features also separate it from *Cypridopsis*. The overlap all around the carapace and the more elongate shape of *Cypridopsella* distinguishes it from *Gutschickia*.

Habitat, fresh water.

GUTSCHICKIA DELTOIDEA (Holland)
Plate 23, figures 1–4

Whipplella deltoidea Holland, 1934, Carnegie Museum Annals, vol. 22, p. 345, pl. 25, figs. 1a–c.

Carapace large, ovate, ends rounded, dorsum strongly arched, venter almost straight; greatest height equals three-fourths greatest length; left valve rises sharply above right along hinge, right overlaps left along middle two-thirds of venter, no overlap on ends; elongate-ovate in dorsal view; valves covered with closely set minute pores; circular muscle scar anteroventral of midpoint; narrow inner flange around anterior end, short and narrow flange around posterior end.

Holotype, Carnegie Museum no. 6482.

GUTSCHICKIA NINEVEHENSIS (Holland)
Plate 23, figures 5–8

Whipplella ninevehensis Holland, 1934, Carnegie Museum Ann., vol. 22, p. 345, pl. 25, figs. 3a–c.

Carapace large; dorsum strongly arched, venter nearly straight; anterodorsal slope long, broadly convex; posterodorsal slope long, nearly straight, steeply inclined; greatest length below median line, greatest height posterior of median; left valve rises above right along hinge, right overlaps left along middle half of venter, no overlap on ends; elongate-ovate in dorsal view; valves covered with closely set minute pores; muscle scar anteroventral of median point; wide inner flange around anterior end, short and moderately narrow flange around posterior extremity.

Holotype, Carnegie Museum no. 6483.

Genus DARWINULA Brady and Norman, 1889

Carapace long, slender; greatest height in posterior third, equal to about one-third of length; dorsum arched; venter nearly straight; ends rounded, anterior end more narrowly rounded, valves unequal, one overlaps other around both ends and venter; hinge simple, valves meet flush or one raised slightly; muscle scar large, forming rosette of approximately nine wedge-shaped small scars with acuminate ends directed toward center.

Only a few living and fossil species of this unusual genus are known.

DARWINULA HOLLANDI Scott, n. sp.
Plate 24, figures 6–8

Carapace small, elongate, narrow; greatest height in posterior third; dorsum broadly arched, anterodorsal slope long, gently convex, posterodorsal slope short, strongly convex; venter straight to gently concave; ends rounded, anterior end more pointed; valves slightly unequal, left slightly overlaps right along free margin, flush along entire dorsum; dorsal view elongate, very narrow, greatest thickness in posterior third; surface smooth.

Holotype, Carnegie Museum no. 24,625. Paratype, University of Illinois no. x-1297. Nineveh limestone, Nineveh, Penn.

There is some question as to whether this species should be referred to *Darwinula*. The length-height ratio of *D. hollandi* is 2.2:1, whereas, in most species of *Darwinula* it is more like 3:1. The smooth contact of the valves along the entire length of the dorsum is rather typical of *Darwinula*. Unfortunately the muscle scars do not show on any of about 20 specimens.

MANUSCRIPT RECEIVED JUNE 25, 1942

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JOURNAL OF PALEONTOLOGY, VOL. 18, NO. 2, PP. 148–155, PLS. 25–27, MARCH 1944

OCCURRENCE OF THE RUSSIAN GENUS RHOMBOTRYPELLA IN UTAH

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ABSTRACT—Described are three new species of *Rhombotrypella*, a Russian late Paleozoic genus not previously recognized in America. They occur in the middle part of the Oquirrh formation, of Des Moines (Middle Pennsylvanian) age, as exposed near Stockton, Utah. Taxonomic significance of perforation in tabulae of Batostomellidae and relation of *Rhombotrypella* to Silurian *Rhombotrypa* and Carboniferous *Rhomboporella* are discussed.

INTRODUCTION

Rhombotrypella was introduced by Mrs. Nikiforova for two Middle Carboniferous (Moscovian) species from the Donetz Basin, but later she found its representatives in the Upper Carboniferous (Uralian) and the Lower Permian (Artinskian) rocks of Russia. The first American specimens of the genus were recognized by Elias in 1940 in a suite of specimens loaned by the U. S. Geological Survey through the courtesy of Dr. James S. Williams. They had been collected by Drs. Gilluly and Girty from the Oquirrh formation near Stockton, Utah, and represent a new species. The other two species were collected by Condra from the Stockton locality in 1941 and 1942.

ORIGINAL GENERIC DIAGNOSIS

The two diagnoses of *Rhombotrypella* published by Nikiforova in 1933 and 1938, describe the same features but in different words. The second definition, which is the more explicit, is as follows:

Zoarium ramose, solid.[1] External surface bear-

[1] We substitute the word "solid" (meaning *not hollow*) in place of "continuous" as in the original text of the English summary, because the latter is an obvious error of translation from the diagnosis in Russian, see p. 57 of the same paper.

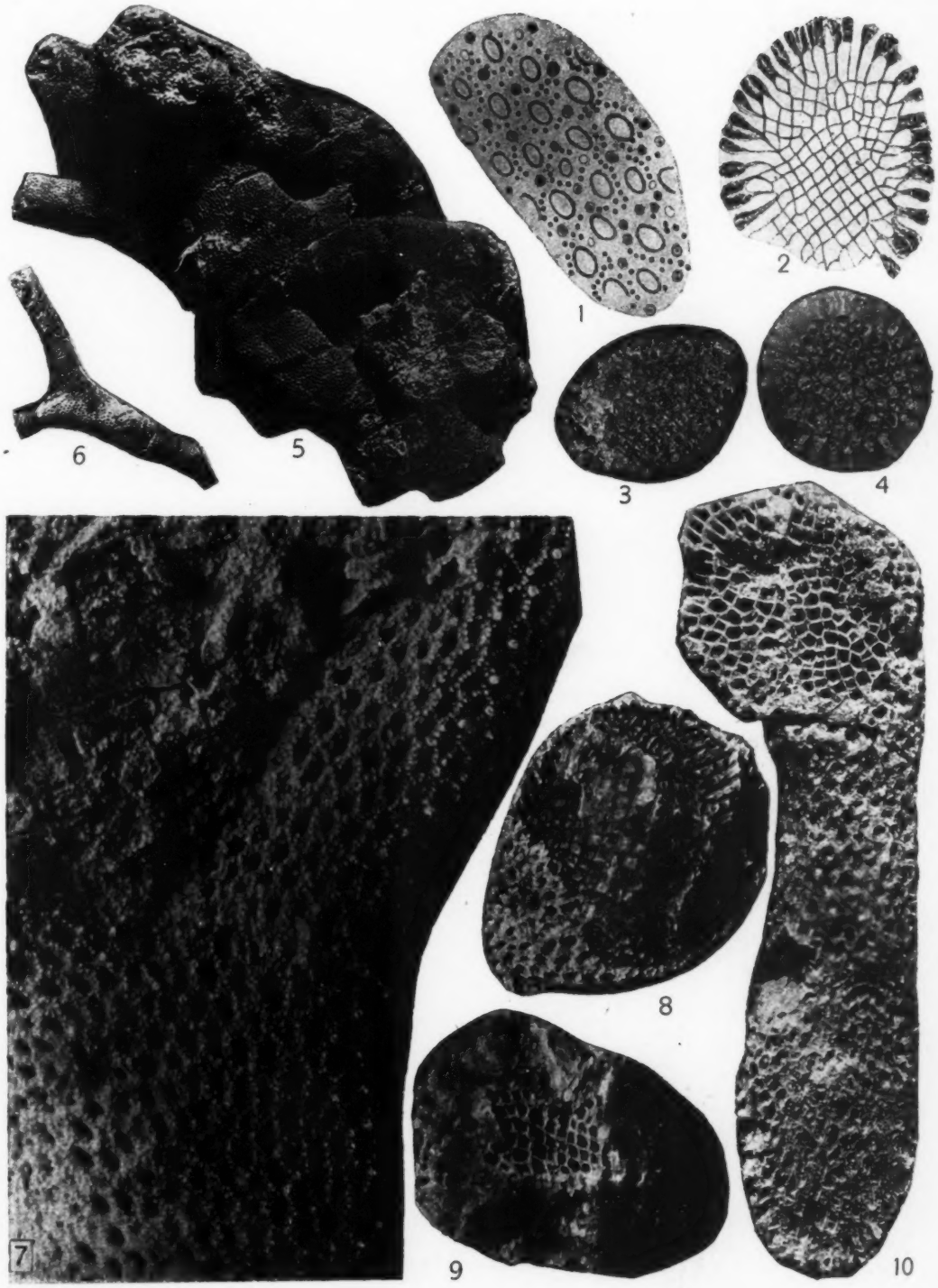
EXPLANATION OF PLATE 25

FIGS. *1–4*—*Rhombotrypella arbuscula* (Eichwald) Nikiforova. Upper Carboniferous (Uralian) of Russia. *1*, Tangential section, to show elliptical zooecia, numerous smaller and fewer larger acanthopores; ×20. *2*, Cross section, to show the differentiation of the zoarium into central, intermediate, and peripheral or cortical regions. The system of rhombic zooecia in the central region is turned 45° in relation to the similar, though slightly less regular, system of rhombic zooecia in the intermediate region; ×11. Holotype, *1* and *2*. After Nikiforova, 1938, pl. 8, figs. 2 and 3. *3*, Homoeotype Nebraska Geol. Survey no. 259. Polished and etched cross section at slightly diagonal orientation, to show the rhombic zooecia of central region. *4*, Homoeotype Nebraska Geol. Survey no. 259-A. Polished and etched cross section to show irregularity in arrangement and outlines of the zooecia, near the tip of a young branch, probably at a point where bifurcation was about to develop. *3* and *4* from the specimens collected by G. E. Condra from the Uralian of Russia; ×10.

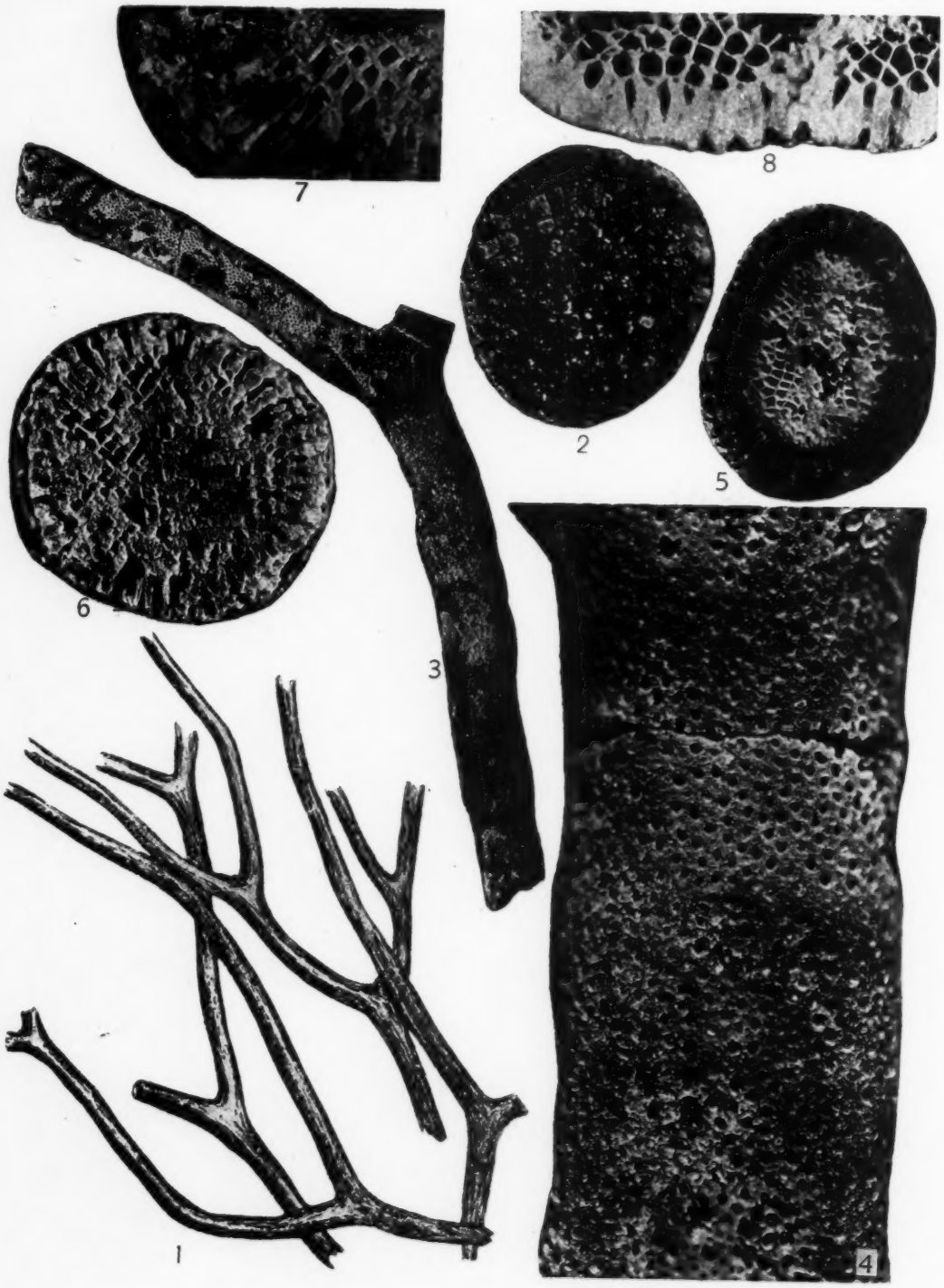
5–10—*Rhombotrypella americana* Condra and Elias, n. sp. Oquirrh formation, Middle Pennsylvanian. About 1 mile west of Stockton, Utah. *5*, Holotype U. S. Geol. Survey no. 5203. Side view, to show lateral fusing of two branches; ×2. *6*, Paratype U. S. Geol. Survey no. 5203-A. Side view of a young, bifurcating branch; ×2. *7*, Same as *5*. Side view to show arrangement and outline of zooecial apertures, and numerous smaller and fewer larger acanthopores; ×20. *8*, Paratype, U. S. Geol. Survey collection. Weathered cross section to show rhombic outline of zooecia; ×10. *9*, Same as *5*. Cross section to show rhombic zooecia in the central part, prepared by natural weathering; ×10. *10*, Same as *5*. Cross section (above) and diagonal section (below) just above bifurcation; to show irregularity in arrangement and outlines of zooecia in a cross section above the point of bifurcation; ×10.

(p. 152)

(Photographs not retouched unless otherwise specified.)



Condra and Elias, Pennsylvanian Bryozoa



Condra and Elias, Pennsylvanian Bryozoa

ing both acanthopores and mesopores. Zooecia in transverse sections of axial region quadrate in outline. Zooecial walls in peripheral part thickened, beaded; perforated diaphragms present (Nikiforova, 1938, p. 223, English summary.)

DISCUSSION

Nikiforova referred *Rhombotrypella* to the Batostomellidae and noted that it is closely related to *Tabulipora* from which it differs in the square outline of the zooecial tubes in transverse sections. She further observed that in this latter respect it resembles Silurian *Rhombotrypa* of the Amplexoporidae, but "the structure of its peripheral part rather sharply distinguishes it from the genus" (Nikiforova, 1933, p. 35—English Summary).

The significance for generic differentiation of the presence or absence of perforations in the diaphragms of some of the Batostomellidae is a matter of discussion and dispute. *Tabulipora*, which Nikiforova considers nearest to *Rhombotrypella*, was originally differentiated chiefly on the basis of the presence of perforated diaphragms (Young, 1883, p. 158). In a subsequent detailed investigation of the British representatives of *Tabulipora* by Lee the genus was considered to consist of two groups of species; those with the diaphragms centrally perforated, and those in which perforation is lateral, that is at the contact of the diaphragm and the lateral wall of the zooecial tube.

Nickles and Bassler (1900, p. 33, 408–409) regarded *Tabulipora* Young to be a synonym of *Stenopora* Lonsdale, but they recognized that the American species of *Stenopora* have diaphragms "perforated centrally." This understanding of *Stenopora* was followed by Condra (1903, p. 40) who described Carboniferous species of the genus from Nebraska and other midwestern states. However, Lee (1912) found that typical species of *Stenopora* have no perforated diaphragms and therefore he considered it to be a genus separate from *Tabulipora*. This view was accepted by Girty (1915, p. 324, 326) who suggested that "all our American Stenoporas must be by this proposal referred to *Tabulipora* and it deserves consideration whether *Stenopora* in its new sense" as revised by Lee "is not the same as *Batostomella*." However, in his subsequent papers Girty continued to use the name *Stenopora* and, judging from his brief remarks (1928, p. 113) and his references of species to this genus (*S. ramosa*, and var. *fayettevillensis*, 1926, p. 859; *S. miseri*, 1926, pp. 849–857; compare with Girty 1910, pp. 198 and 196–197, respectively), he included in it the species with perforated diaphragms. On the other hand, Bassler (1929, p. 54) accepted *Tabulipora* in the restricted sense for the species with perforated diaphragms, and retained *Stenopora* for those with "complete diaphragms." In addition he considered the "beaded walls" to be characteristic of both.

Nikiforova (1933, p. 4 and 34; 1938, p. 51–52, 219) accepted the differentiation of *Stenopora* and *Tabulipora* as recognized by

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EXPLANATION OF PLATE 26

FIGS. *1–2—Rhombotrypella arbuscula* (Eichwald) Nikiforova. Upper Carboniferous (Uralian) of Russia. *1*, Side view of ramose zoarium. Holotype, ×1. After Nikiforova, 1938, pl. 8, fig. 1. *2*, Polished and etched cross section of a specimen collected by G. E. Condra from the Lower Permian of Russia; ×10. Retouched.

3–7—Rhombotrypella nikiforovaea Condra and Elias, n. sp. Oquirrh formation, Middle Pennsylvanian. About 1 mile west of Stockton, Utah. *3*, Holotype Nebraska Geol. Survey no. 261. Side view; ×2. *4*, Same as *3*. Side view to show maculae consisting of groups of undeveloped zooecia mixed with a few normally developed zooecia; ×10. *5*, Same as *3*. Cross section of somewhat crushed branch, to show the preserved portions of the central region, the intermediate region where the system of rhombic zooecia is oriented at 45° in relation to the similar system in the center, and the peripheral or cortical region; ×10. *6*, Paratype Nebraska Geol. Survey no. 262. Cross section of uncrushed branch showing same features as *5*; ×10. *7*, Same as *3*. Part of cross section to show development of solid (nonperforate) tabulae in the intermediate region; ×20. (p. 153)

8—Rhombotrypella regularis. Same as pl. 27, fig. 3. Part of cross section of crushed branch to show rhombic outline of zooecia and the widely and centrally perforated diaphragms; ×20. (p. 154)

(Photographs not retouched unless otherwise specified.)

Lee and Bassler, but she noted that in *Tabulipora* the walls are not always beaded. Furthermore, in the detailed description of species she stated that diaphragms are "continuous" (solid), "centrally perforated" and "unilaterally perforated," all in the same specimen of *Tabulipora maculosa* Nikiforova (pp. 54 and 220). She remarked that "this mixed character of diaphragms could not be explained" by her "since on the base of the scanty material in hand there was no possibility to decide whether this is a constant specific character or merely an occasional one" (p. 220). Nikiforova also observed both solid and perforated diaphragms in several species of *Rhombotrypella*.

In his lists of identified fossils from the Oquirrh formation Girty (1932, pp. 36–37) recorded the following forms, one or all of which might correspond to *Rhombotrypella*, which we describe from the same locality and partly, from the same collections: *Lioclema*[2] sp. *Stenopora* sp., *S.* aff. *carbonaria*, and *Batostomella* sp.

All of our species of *Rhombotrypella* possess centrally perforated diaphragms; but *R. nikiforovae*, n. sp., also has solid ones.

METHOD OF STUDY

All specimens collected from the Oquirrh formation at Stockton are silicified to various degrees but the matrix, which is fine-grained argillaceous sandstone with calcareous cement grading locally to limestone, is generally not silicified and the fossils stand out in relief on the naturally weathered surfaces of the rock. Because replacement of the original calcite in the fossils by silica apparently proceeded without serious damage to structural details, and because this silicification occasionally advanced at unequal rates in anatomically different tissues, subsequent weathering has resulted in sharp differentiation of some morphological and anatomical details and makes possible their observation in three dimensions. Similar details can usually be observed on freshly broken surfaces etched with acid.

In order to observe the inner structure of fossils it is ordinarily necessary to prepare polished sections or transparent slides. Lee studied the tabulae of *Tabulipora* by this method. In his diagram (Lee, 1912, Pl. XIV, figs. 1A, 1B, 2A, 2E; reproduced by Nikiforova, 1938, p. 52, Fig. 18) he showed that, depending on where the cut is made, the same perforated tabula may appear in a section as solid, or slightly to broadly perforated; also laterally perforated tabulae may appear in some sections as if they were centrally perforated. Because of the differential silicification and subsequent natural weathering or artificial etching, the tabulae in our *Rhombotrypella* from near Stockton can be studied directly, instead of in sections. The advantages of such study are obvious. Photographs of complete tabulae, solid and perforated, are presented on Pl. 2, (figs. 7 and 8, ×20).

DIAGNOSIS OF RHOMBOTRYPELLA

On the basis of additional species from Utah the generic diagnosis of *Rhombotrypella* is modified as follows:

Zoarium ramose, solid, with repeated bifurcations usually in about same plane. Neighboring branches occasionally fused (in *R. americana*). Surface of branches even or undulating. Zooecial apertures without regular arrangement or more or less in diagonal to transverse rows. Undeveloped zooecia variable in number and arrangement; in some species grouped in maculae (*R. stuckenbergi*, *R. nikiforovae*), or in regular rows (*R. regularis*). Acanthopores developed in cortical area, usually differentiated into numerous small and fewer large ones, the latter ordinarily located at intersections of walls. Cortical and axial areas sharply differentiated. Axial area in some species differentiated into central part and peripheral or intermediate part or zone. As viewed in cross sections, zooecia subrectangular—rhombic to square in outline, regularly arranged in two systems of parallel rows intersecting at angle of nearly or exactly 90°. If intermediate zone is differentiated, most of its zooecia have same regular shape and arrangement, but whole system of rows is turned at about 45° angle from system in central area. At and above points of bifurcations of zoarium, zooecia of axial region usually irregularly arranged, pentagonal or

[2] The original spelling of this genus is *Leioclema* (Ulrich, 1882) but about 50 years ago it was changed to *Lioclema* in most paleontological publications and text-books.

KEY TO THE SPECIES OF RHOMBOTRYPELLA

Species	Zoarium: Cross-section: Shape	Zoarium: Cross-section: Size in mm.	Zoarium: Thickness of cortical area in mm.	Zooecia: Number in 2 mm. at surface	Zooecia: Number in 1 mm. in axial part	Tabulae	Additional Important Characters
R. arbuscula distincta, L. Permian (Artinskian?)	Circular	Dia. 2.5	0.5	4.5–5	5.5–6	Mixed; solid and centrally perforated	Nearly regular rows of zooecia
R. arbuscula, Uralian (C_3^2)	Circular	Dia. 2.5–3	0.4	5	5.5–6	Mixed; solid and centrally perforated	
P. stuckenbergi, Uralian (C_3)	Somewhat irregular	Dia. ca. 18.0	abt. 2.0	7–9	5	Mixed; solid and centrally perforated	Very thick growth. Monticules
P. astragaloides, Moscovian (C_4^2 of Donetz Basin)	Circular	Dia. 6.5	abt. 2.0	4–5	abt. 5	Centrally perforated	Bead-like walls in cortical area
P. simplex, Moscovian (C^2 of Donetz Basin)	elliptical	3×5	1.0	5–6	5–5.5	laterally (?) perforated	Walls without bead-like constrictions
P. americana, Condra and Elias, Des Moines of Utah	elliptical	2.5×4 to 4×6	0.1–0.4	6–9	5–7	Centrally perforated	
P. nikiforovae, Condra and Elias, Des Moines of Utah	elliptical	3×4 to 4×5	0.6	5–6	5–6.5	Mixed; solid and centrally perforated	Monticules
P. regularis, Condra and Elias, Des Moines of Utah	elliptical	2.5×4 to 3×5	0.35–0.4	6–7	5–5.5	Centrally perforated	Transverse rows of undeveloped zooecia

hexagonal in cross section, showing some tendency to radial arrangement.

Thick walls of cortical tissue of nearly uniform thickness, but in some species, usually with thick cortical tissue, repeated constrictions produce beadlike effect.

Tabulae generally centrally perforated, in some species both perforated and solid tabulae present.

OCCURRENCE AND RANGE

The new species occur in the middle zone of the middle or fossiliferous part of the Oquirrh formation and were collected at several places at the eastern end of South Mountains, about 1 to 1½ miles west of Stockton, Utah. In Russia the genus is present in beds from the Middle Carboniferous (Moscovian) to Lower Permian (Artinskian).

The American species occur in beds of about the same age as those from which the Russian species were originally described, i.e. Middle Carboniferous or Moscovian, correlated with our Des Moines. Their relations to the Russian species are discussed in connection with their description. Measurements and other essential data for the Russian species are presented in the accompanying table and illustrations of *R. arbuscula*, a typical Russian species, are given on plate 25 (figs. 1–4), plate 26 (fig. 1), and plate 27 (fig. 1).

COMPARISONS

Rhombotrypella Nikiforova (1933) resembles *Rhombotrypa* Ulrich and Bassler (1904) from the Silurian of North America and *Rhomboporella* Bassler (1936) from the Carboniferous of South America in that they all possess similar regular arrangement of zooecia in the axial region which results in the rhombic to quadrate shape of zooecia in cross section.

The difference between *Rhombotrypella* and *Rhombotrypa*, as pointed out by Nikiforova, lies in the structure of the peripheral or cortical region. *Rhombotrypa* has no acanthopores, or only single acanthopores at the corners of zooecial walls developed at the surface but not extending inside the cortical region. In addition, however, the tabulae of *Rhombotrypa* are invariably solid, but in *Rhombotrypella* they are commonly centrally perforated although some species have both solid and perforated tabulae.

The genotype of *Rhombotrypa*, and other species which Ulrich and Bassler (1904, p.

44–47) refer to this genus, are all of Richmond (late Ordovician or early Silurian) or Niagaran (Silurian) ages; the genus has not been recognized in Devonian or younger rocks.

Rhombotrypella and *Rhomboporella* both have well-developed acanthopores of two kinds, large and small; but *Rhomboporella* differs in having superior hemisepta, which may be regarded as remnants of tabulae perforated by large, excentric openings.

These three genera, although so similar, have been referred to three different families as follows: *Rhombotrypa* to *Amplexoporidae* Ulrich, *Rhombotrypella* to *Batostomellidae* Ulrich, and *Rhomboporella* to *Rhabdomesontidae* Vine. The similarity of rhombic or quadrate outline of zooecia in transverse section has been explained by Ulrich and Bassler (1904, p. 45) and by Bassler (1936) as an "interesting case of parallel development," caused "by the fact that the zooecia in the immature zone simultaneously at definite intervals develop new tubes and undergo a change in orientation of their sides" (Bassler, 1904, p. 159).

Specimens of *Rhombotrypa* from the Silurian of Oxford, Ohio, in the University of Nebraska State Museum, reveal additional similarities between this genus and *Rhombotrypella* from the Oquirrh formation of Utah. Some specimens of *Rhombotrypa* have the same differentiation of the axial region into central and intermediate zones as does *Rhombotrypella*, and the systems of zooecia in the two have the same mutual orientations, one being diverted 45° from the other. This feature is well illustrated in the photograph of a cross section of *Rhombotrypa* published by Bassler (1932, pl. 24, fig. 19), but it has not been described or explained.

In other Oxford specimens of our collection, the zooecial apertures tend to be arranged in regular curving diagonal to transverse rows, similar to those in *Rhombotrypella regularis*, n. sp., from the Oquirrh formation.

The incomplete cross section of *Rhomboporella* illustrated by Bassler (1936, fig. 12, or p. 158) also shows in the upper right part a slight indication of the development of a narrow intermediate zone of rhombic zooecia turned 45° from those in the central zone.

This evidence suggests that, *Rhombotrypa*, *Rhombotrypella* and *Rhomboporella* are more closely related than has been thought, and perhaps they should be united in a single family. The fact that in some species of *Rhombotrypella* the tabulae are of mixed character, some solid, and others perforated, seems to indicate that the difference in perforation or nonperforation of tabulae, is not necessarily of sufficient importance to distinguish families, genera or even species, unless combined with other distinctive characters.

RHOMBOTRYPELLA AMERICANA
Condra and Elias, n. sp.
Plate 25, figures 5–10

This species is established on several specimens collected by Gilluly and Girty. The best specimen, selected as holotype, is a group of several fragments, evidently broken parts of a single zoarium. The largest fragments bifurcate at intervals of about 20 mm., and shows one complete lateral grafting or fusion of two branches (pl. 25, fig. 5), a feature not previously observed in *Rhombotrypella*. Similar lateral fusion of branches, however, is known to occur occasionally in related *Lioclema*.

Although most branches in this species are more or less laterally crushed the few which are not damaged show distinct elliptical rather than circular cross section. Branching takes place in such manner that axes of all branches remain in about the plane of the long diameters of their cross sections. Crushing of branches is invariably perpendicular to this plane.

Thickness of the branches varies from $2\frac{1}{2} \times 4$ mm. in the youngest to 4×6 mm. in the oldest and their surfaces are nearly even to very gently undulating. Zooecia at the surface show little regularity in arrangement and shape; they also vary in size and from 6 to 9 occur per 2 mm. At the surface the smallest zooecia is about 0.1×0.2 mm. and the largest about 0.2×0.4 mm. Small, undeveloped zooecia occur sporadically and without order among the larger ones. In the walls between zooecia are small but well developed acanthopores, arranged in a single row but commonly they are somewhat out of line and occasionally they tend to form two irregular rows. At some intersections of

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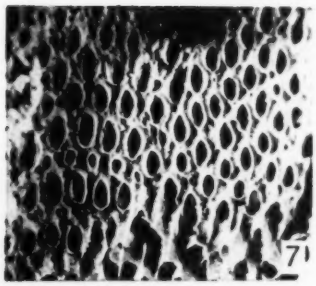
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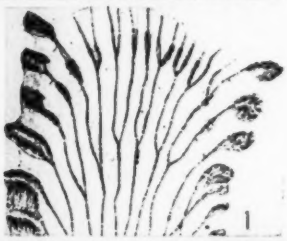
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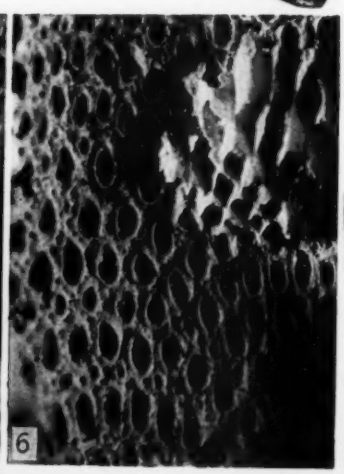
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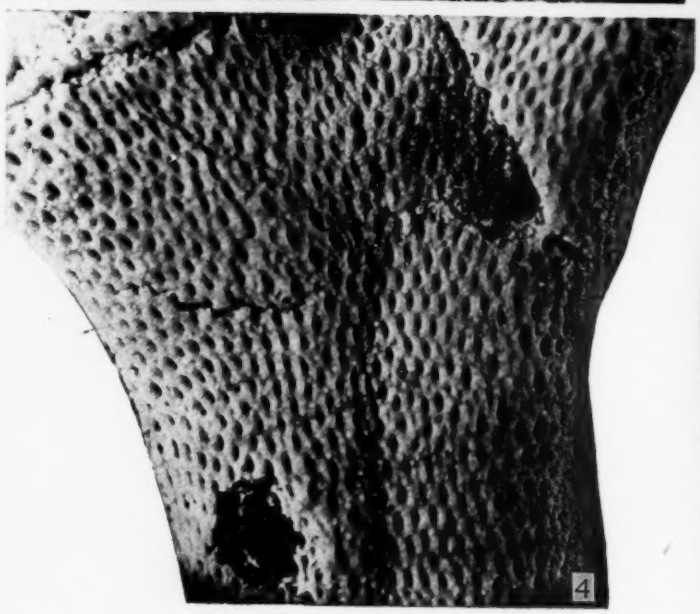
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Condra and Elias, Pennsylvanian Bryozoa

UNIV. OF MICH.

the walls are single acanthopores about two to three times as thick as the others and more prominently elevated (pl. 25, fig. 7).

When viewed in cross section the branches show sharply differentiated axial and cortical areas. The latter are from 0.2 to 0.4 mm. thick and show no bead-like design of thick walls. Zooecia in the central part of the axial area are arranged very regularly, so that their walls form two systems of parallel lines crossing at nearly 90° angles and each tube is rhombic-subrectangular to nearly perfectly square. Between the central part of axial region and the cortical region there is commonly an intermediate zone about 2, 3 or 4 cells thick. In it the zooecia are as rectangular as in the central part, or variously modified to irregular pentagonal and hexagonal shapes. Rectangular zooecia are arranged in two systems of nearly perpendicularly interesecting rows, as in the central part, but these rows diverge at an angle of about 45° from the rows of zooecia in the central part.

Rectangular zooecia occur 5 to 5½ per millimeter in the central part and 6 to 7 per millimeter in the intermediate zone, where they are usually smaller.

The regular arrangement and rectangular cross sections of zooecia may be completely lost at some bifurcations of the zoarium and irregular arrangement and cross sections may persist for 3 to 5 millimeters or more above. In these parts the zooecia of the axial area commonly show a tendency to radial arrangement, but this rapidly disappears and the typical arrangement is resumed.

Tabulae are commonly developed at the inner side of the cortical region. They are widely perforated centrally and only a narrow circular border is adherent to the walls. The edge of each tabula is slightly thickened around the nearly circular perforation.

Discussion.—This species is most similar to the Russian *R. arbuscula* but differs in the less regular arrangement of its zooecia at the surface, in the smaller average size of the zooecia and their greater diversity in size, in the elliptical cross section of branches, their more frequent bifurcation and occasional lateral grafting or fusion. It differs from *R. nikiforovae*, n. sp., in the absence of monticules and general scarcity of the small, undeveloped zooecia at the surface, and from *R. regularis* n. sp. by the irregular arrangement of zooecia at the surface and their smaller size.

Holotype.—U. S. Geological Survey No. 5203.

RHOMBOTRYPELLA NIKIFOROVAEA
Condra and Elias, n. sp.
Plate 26, figures 3–7, plate 27, figure 2

A single well preserved specimen, the holotype, is the chief basis for the following description. Several smaller and less well preserved specimens in the same collection add little to an understanding of the species.

The holotype is about 70 mm. long, branching only once. Judging from distance of the bifurcation to the farthest end of the

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EXPLANATION OF PLATE 27

FIG. *1*—*Rhombotrypella arbuscula* (Eichwald) Nikiforova. Upper Carboniferous (Uralian) of Russia. Holotype. Axial section; ×11. After Nikiforova, 1938, pl. 8, upper part of fig. 4.

2—*Rhombotrypella nikiforovae* Condra and Elias, n. sp. Same as pl. 26, fig. 6. Axial section, polished and etched; ×10. (p. 153)

3–7—*Rhombotrypella regularis* Condra and Elias, n. sp. Oquirrh formation, Middle Pennsylvanian, about 1 mile west of Stockton, Utah. *3*, Holotype Nebraska Geol. Survey no. 263. Side view; ×2. *4*, Same as *3*. Side view, to show tendency to regular arrangement of the apertures and the occasionally intercalated transverse rows of undeveloped zooecia; also the numerous smaller and less numerous larger acanthopores; ×10. *5*, Same as *3*. Side view of the lower part of the uncrushed right lower branch. To show same features as in *4;* ×10. *6*, Same as *3*. View of the inner surface of the cortical area exposed by weathering. To show transverse rows of undeveloped zooecia and smaller holes which correspond to smaller and larger acanthopores. In the right upper corner is a group of partly preserved zooecial tubes of the intermediate region; ×20. *7*, Same as *3*. View of the inner surface of the cortical region. To show the same features as in *6;* ×20. (p. 154)

(Photographs not retouched unless otherwise specified.)

fragment, points of bifurcation we spaced 45+ mm. apart, being in this respect similar to the Russian *R. arbuscula* (pl. 26, fig. 1). The holotype is slightly crushed and a thin zone of telescoped and compressed zooecial tubes is present in the central part. This crushing has exaggerated the elliptical cross section of the zoarium but judging from the least crushed portions of the branches their transverse dimensions were about 3×4 mm. to 4×5 mm. The long axis of the cross section is in the plane of bifurcation.

The surface of the branches is nearly even with only gently rising undulations, some of which coincide with the few small monticules 0.5 to about 1.3 mm. in diameter. These are formed by groups of small, undeveloped zooecia commonly with two or three normally developed zooecia scattered among them. The ordinary zooecia are subcircular to circular in outline and show little regularity in arrangement. Numerous much smaller, undeveloped zooecia are scattered among the larger ones.

The acanthopores are very small and form a single row in the middle of the zooecial walls. Somewhat more prominent acanthopores occur at points of junction of the walls.

As viewed in cross section the cortical area is sharply separated from the axial area and the latter is less distinctly divided in central and peripheral or intermediate zones. The central zone is slightly but distinctly excentric and on one side directly contacts the cortical area (pl. 26, fig. 6). All zooecia in the central zone are arranged in two systems of regular rows crossing at nearly right angles and are rhombic-subrectangular to square in outline. Zooecia in the intermediate zone are arranged in similar rows, but these diverge from those in the central part at an angle of about 45°. In the central and intermediate zones zooecia occur 5 to 6.5 per millimeter. The cortical area is 0.6 mm. thick and is characterized by thick walls between the zooecial tubes. Tabulae are developed mostly near the division between cortical and axial areas, and are scattered within the latter where they are solid, although the other tabulae have wide, central perforations.

Discussion.—The presence of monticules differentiates this species from *R. americana* and *R. regularis*. The Russian *R. stuckenbergi* also has monticules, but differs from this species by its much thicker growth form and very thick cortical area.

Holotype.—Nebraska Geol. Survey no. 261.

Rhombotrypella regularis

Condra and Elias, n. sp.

Plate 26, figure 8; plate 27, figures 3–7

Only one undoubted specimen of this species has been found but this is one of the best-preserved representatives of the genus in the collection of the Nebraska Geological Survey. It is part of a ramose zoarium 45 mm. long, and includes two bifurcations about 30 mm. apart. The longest branch is somewhat crushed in the plane of bifurcation, which coincides with the longer diameter of the transversely elliptical branches as shown by the other uncrushed branches. In cross-sections the upper younger branch measures 3×4 mm. and the older, lower branch 4×5 mm.

The surface of the uncrushed lower branch is prominently but somewhat irregularly undulating. Zooecia at the surface are mostly longitudinally elongated parallel to the axis of the branch and tend to be arranged in transversely diagonal rows.

On each broader side of a branch, that is on the side parallel to the plane of bifurcation, the diagonal rows of zooecial apertures curve gently in featherlike fashion as they diverge to the right and left. The angle of divergence near the center is acute, but as the rows of the apertures approach the lateral, shorter sides of the branch they become nearly to quite transverse to its axis. This transversely diagonal and curved arrangement of zooecia is emphasized by the occasional intercalation of similarly arranged small, undeveloped zooecia. The latter vary from 0.07 to 0.1 mm. in long diameter; the long diameters of normally developed zooecia vary from 0.15 to 0.45 mm. Acanthopores are present in a single row between zooecia, and a thicker and taller acanthopore is developed at each point of junction of the walls. Such larger acanthopores also appear occasionally singly between the small acanthopores in the walls (pl. 27, fig. 4).

The cortical and axial areas are sharply differentiated in cross sections of branches.

The structural differentiation results also in mechanical differences between the much stronger cortical part and the weak axial part. Thus when there is no secondary filling of zooecial tubes, as in our specimen of *R. nikiforovaea*, the axial part is easily crushed and weathered out, while the cortical part remains intact and its inner side may be partially exposed and show both normal and undeveloped zooecia sharply outlined and exceptionally well preserved. Acanthopores may also be seen clearly as they appear as small circular holes within the walls. Tabulae are commonly developed at the inner side of the cortical tissue and also somewhat farther inside the branch (pl. 26, fig. 8). They all have a very large circular central perforation and are represented only by a narrow flange on the inner side of the tube.

In cross section the axial part is divided by two nearly perpendicular systems of parallel walls into rhombic-subrectangular to nearly square zooecia. Because of the imperfection of preservation of the weak axial part it is not clear whether there is any differentiation of it into a central part and an intermediate zone or ring next inside the cortical part, as in *R. americana*. Zooecia in the axial part number about 5 to 5.5 per millimeter.

Discussion.—This species differs from *R. americana*, *R. nikiforovaea*, and all Russian species by the regular transversely diagonal arrangement of its zooecial apertures and by the abundance of small undeveloped zooecia which are arranged in similar rows.

Holotype.—Nebraska Geol. Survey no. 263.

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JOURNAL OF PALEONTOLOGY, VOL. 18, NO. 2, PP. 156–161, PL. 28, MARCH 1944

NEW OSTRACODA FROM SUBSURFACE MIDDLE TERTIARY STRATA OF TEXAS[1]

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ABSTRACT—Twelve new species of Ostracoda are described from the *Discorbis*, *Heterostegina*, and *Marginulina* zones of the middle Tertiary section of the Gulf Coast.

THE Ostracoda described were obtained from strata well known to workers on the subsurface Tertiary of the Gulf Coast as the *Discorbis*, *Heterostegina*, and *Marginulina* zones. Paleontologists have never reached agreement on the age of these beds whose faunas bear affinities to both Oligocene and Miocene.

Several species of smaller Foraminifera from these strata have been described by J. B. Garrett and A. D. Ellis, Jr. (1937). In a later paper, Garrett (1939) further amplified the list of described Foraminifera from these horizons. The present report on the Ostracoda contains descriptions of only the more common and distinctive species present. The material has been checked against primary types of species described from the Oligocene and Miocene of the Gulf Coast wherever possible, and an attempt has been made to distinguish the species in the faunas of surface localities.

The specimens studied were obtained from cores of Stanolind Oil and Gas Company no. B-2 Pipkin, Big Hill prospect, Jefferson County, Texas, and from Magnolia Petroleum Company no. 1 H. B. Funchess, Jr., Jefferson County, Texas. Types of new species will be deposited in the Louisiana State University Museum, Baton Rouge, Louisiana.

I am indebted to J. B. Garrett for suggesting this study, and for advice during its progress. Through the courtesy of Henry V. Howe, I obtained equipment necessary for drawing the illustrations, and studied a number of type specimens of Gulf Coast Ostracoda in the Louisiana State University Museum.

[1] Published with the permission of the Stanolind Oil and Gas Company.

SYSTEMATIC DESCRIPTIONS

Family CYPRIDAE Baird, 1846

Genus BAIRDIA McCoy, 1844

BAIRDIA? CRUMENA Stephenson, n. sp.

Plate 28, figure 5

Carapace in side view subrhomboidal, somewhat elongate. Left valve slightly longer than right, strongly overlapping on dorsal side, to lesser extent on ventral side. Dorsal and ventral margins subparallel, nearly straight. Anterior end bluntly rounded; posterior end narrower, somewhat produced into roundly pointed beak. Surface rather strongly sculptured, pits elongate, closely spaced, of moderate size and depth covering entire exterior. Well-defined angular ridge, near and subparallel to the dorsal margin, extends almost entire length of carapace. Broader horizontal ridge, thickened at center, extends from anterior to posterior ends somewhat below center of shell, interrupted at about anterior one-fourth by broad notch.

Length, 0.61 mm.; height, 0.34 mm.; width, 0.31 mm.

Type: Holotype no. 2298, from core at 6311–6313 feet, Magnolia Petroleum Company no. 1 H. B. Funchess, Jr., Jefferson County, Texas.

A search of available literature has failed to accurately place this species generically. Known species of *Bairdia* are characterized by an exterior which is smooth or in some cases has minor pitting. This species, with its strong ornamentation, appears generically distinct. It seems ill-advised, however, to erect a new genus from subsurface material, and available specimens are limited. I have a similar but distinct species of this genus from the Recent of Cuba.

Family CYTHERIDAE Baird, 1850
Genus CYTHEREIS Jones, 1849
CYTHEREIS HANNAI Stephenson, n. sp.
Plate 28, figures 11, 12

Cythereis sp. 19, Howe, 1934, Guide Book, Eleventh Annual Field Trip of Shreveport Geol. Soc., pl. 1, figs. 19–21.

Carapace in side view oblong, subquadrate, highest at anterocardinal angle. Dorsal and ventral margins nearly straight, converging slightly toward posterior. Anterior end rounded, with thickened marginal rim. Posterior end compressed, bluntly angulate, with less prominent rim, bearing several short, roundly pointed spines. Entire surface rugged, highly sculptured, with deep pits surrounded by irregular pattern of coalescing ridges of variable prominence. Angular ridge, extending from midpoint of dorsal margin and obscuring it, ends abruptly near posterocardinal angle. Thickened, well-elevated protuberance, somewhat anterior to middle of shell strongly ornamented by pits and irregular ridges. Anterior rim continues near ventral margin as slender, fluted ridge, rising obliquely onto carapace wall, terminating abruptly about one-third the shell length from posterior in bluntly spinose projection.

Length, 0.74 mm.; height, 0.45 mm.; width, 0.41 mm.

Types: Holotype no. 2350, from core at 6034–6037 feet, and paratypes nos. 2351, 2352, from bottom of core at 6062–6066 feet, Stanolind Oil and Gas Company no. B-2 Pipkin, Jefferson County, Texas. Paratype no. 2353, from lower Chickasawhay Miocene, "Limestone Creek Church locality," Wayne County, Mississippi (see loc. CC-1, Eleventh Guide Book, Shreveport Geol. Soc., p. 40, 1934).

This highly sculptured species occurs rather commonly in subsurface strata. It has been reported by Howe (1934) from the Chickasawhay Miocene of Mississippi.

Named for Marcus A. Hanna, Gulf Oil Corp., Houston, Texas.

CYTHEREIS MACERTA Stephenson, n. sp.
Plate 28, figures 6, 7

Carapace small, in side view subrhomboidal, elongate, compressed. Dorsal margin low, straight, sloping gently to posterior; ventral margin straight or slightly sinuated. Anterior end rounded, bearing numerous very short, knoblike spines; posterior end steeply sloping to blunt posteroventral angle, denticulate like anterior. Surface bears rather irregularly disposed pits of moderate size. Peripheral rim extends from eyespot around anterior, ventral and posterior margins. Narrow dorsal ridge forms arc beginning below and behind eyespot, extending back to point inside posterocardinal angle, where it coalesces with elevated, irregular knob of clear shell material. Slight inflation or ridge often extends from this knob laterally toward anterior, shell wall excavated dorsally and ventrally.

Length, 0.61 mm.; height, 0.29 mm.; width, 0.21 mm.

Type: Holotype no. 2299, from core at 5846–5851 feet, Stanolind Oil and Gas Company no. B-2 Pipkin, Jefferson County, Texas.

CYTHEREIS VERRUCOSUS
Stephenson, n. sp.
Plate 28, figure 15

Carapace in side view elongate-ovate; valves subequal, left slightly overlapping right. Dorsal margin weakly arched, rising somewhat around well-developed eyespot, sloping gently to weak posterocardinal angle. Ventral margin convex, rising posteriorly. Anterior end broadly rounded, faintly rimmed, weakly denticulate; posterior end bluntly pointed. Surface ornamentation somewhat variable, commonly of fairly closely spaced, fine, short spines. Shell wall may carry numerous small papillae, perhaps indicating eroded remnants of spines or their failure to completely develop. Carapace of some specimens only slightly irregular, granular. No break in the gradational development of ornamentation apparent.

Length, 0.82 mm.; height, 0.52 mm.; width, 0.46 mm.

Types: Holotype no. 2354, from core at 5905–5908 feet, and paratypes nos. 2355, 2356, from core at 5727–5732 feet, Stanolind Oil and Gas Company no. B-2 Pipkin, Jefferson County, Texas.

C. verrucosus resembles *C. garretti* Howe and McGuirt (see Howe, H. V., and others, 1935, pp. 20, 21, pl. 3, figs. 17–19) from the

Miocene of Florida. The new species is, however, very much smaller, and less inflated on the posterior, with a more strongly sloping hinge line, and a more convex ventral margin. This species is smaller and higher than *C. clarkana* (Ulrich and Bassler) from the Miocene of Maryland, and shows no tendency toward the coalescing pattern of ridges and pits of the Maryland species.

Genus ALATACYTHERE Murray and Hussey, 1942

ALATACYTHERE WESTI Stephenson, n. sp.
Plate 28, figures 3, 10

Carapace in side view subrhomboidal, elongate. Left valve slightly larger. Dorsal margin straight, sloping gently toward posterior. Anterior end broadly rounded, posterior end subtriangular, compressed, armed with several short, blunt spines on ventral half. Fairly strongly projecting ala, near and paralleling ventral margin, continues as slender, fluted rim around anterior end. Remainder of valves smooth, except for short, low ridge somewhat below and in front of posterocardinal angle. Hinge line characteristic of the genus *Alatacythere*, posterior tooth of right valve notched to form several distinct cusps. Marginal zones of moderate width, about 15 radial pore canals on anterior, rather irregularly disposed, in part bifurcating.

Length, 0.79 mm.; height, 0.42 mm.; width, 0.48 mm.

Types: Holotype no. 2357, from core at 5960–5963 feet, and paratype no. 2358, from core at 5846–5851 feet, Stanolind Oil and Gas Company no. B-2 Pipkin, Jefferson County, Texas.

This species bears some resemblance to *Cythereis* (*Pterygocythereis*) *cornuta* (Roemer) var. *americana* Ulrich and Bassler (1904, pp. 122, 123, pl. 37, figs. 29–33) from the Miocene of Maryland. The Maryland species is much larger, however, as Ulrich and Bassler (1904, p. 122) indicate the length of a relatively short left valve to be 1.10 mm. Specimens from Maryland likewise are more strongly spinose on anterior and posterior, with a slender, keellike, fluted crest along the dorsal margin, and the posterior tooth in the hinge of the right valve shows no crenulations. An undescribed species of *Pterygocythereis* from the *Chione* limestone of the lower Chickasawhay of Mississippi is similar, but is lower and more elongate, with the *Cythereis* type of hingement.

Named for Frank West, Shell Oil Co., Houston, Texas.

Genus HEMICYTHERE Sars, 1925

HEMICYTHERE AMYGDALA
Stephenson, n. sp.
Plate 28, figures 8, 9

Carapace in side view almond-shaped, in dorsal view lenticular. Anterior end obliquely rounded, posterior end rounded but narrower, faintly pointed. Dorsal margin gently arched between weak cardinal angles; ventral margin somewhat convex, indented toward posterior. Entire surface covered with rather closely spaced, shallow pits of moderate size. Less tumid portions of carapace carry low, curvilinear ridges paralleling periphery, which coalesce around pits.

Length, 0.57 mm.; height, 0.37 mm.; width, 0.26 mm.

Type: Holotype no. 2359, from core at 5876–5880 feet, Stanolind Oil and Gas Company no. B-2 Pipkin, Jefferson County, Texas.

A somewhat similar form, *H. conradi* Howe and McGuirt (see Howe, H. V., and others, 1934, pp. 27, 28, pl. 3, figs. 31–34; pl. 4, fig. 17) occurs in the Miocene of Florida. A comparison with the original types of the Florida species indicates *H. amygdala* to be much more ovate in side view with more obscure cardinal angles, with a finer and more closely spaced pitting pattern.

HEMICYTHERE SAGINATA Stephenson, n. sp.
Plate 28, figures 16, 17

Carapace in side view subovate, strongly inflated. Anterior end obliquely rounded, dorsal margin gently arched joining it in even curve. Ventral margin convex, somewhat indented toward anterior and posterior. Posterior end bluntly angular, may be obscurely spinose. Surface covered with rather shallow pits of variable size. Slight nodose projection developed on inflated shell wall near ventral margin, about one-fourth the shell length from posterior. Eye-

spot faintly visible, from which low, rounded marginal rim extends around anterior end.

Length, 0.79 mm.; height, 0.52 mm.; width, 0.48 mm.

Type: Holotype no. 2360, from core at 6311–6313 feet, Magnolia Petroleum Company no. 1 H. B. Funchess, Jr., Jefferson County, Texas.

Genus CYTHERIDEIS Jones, 1849

CYTHERIDEIS RUGOSUS Stephenson, n. sp.

Plate 28, figure 4

Carapace in side view low, elongate. Dorsal margin nearly straight between weak cardinal angles, sloping gently toward posterior. Ventral margin straight or faintly sinuated, slightly produced ventrally at posteroventral angle of right valve. Anterior end obliquely rounded, obscurely spinose; posterior end bluntly truncated to narrowly rounded posteroventral angle. Surface rather weakly pitted, with reticulate pattern of low, irregular ridges coalescing around pits. Hinge structure typical for genus.

Length, 0.68 mm.; height, 0.33 mm.; width, 0.29 mm.

Type: Holotype no. 2370, from core at 5647–5651 feet, Stanolind Oil and Gas Company no. B-2 Pipkin, Jefferson County, Texas.

The new species is distinguished from *C. ashermani* Ulrich and Bassler (1904, p. 126, pl. 37, figs. 10–16) from the Miocene of Maryland, by its smaller size and finer pitting. *C. rugosus* differs from *C. longula* Ulrich and Bassler (1904, pp. 128, 129, pl. 37, figs. 21–27) in having a smaller carapace which is higher on the anterior. The surface ornamentation of the new species is also much finer, with no trace of the anterior rim which is characteristic of *C. longula*.

Genus HAPLOCYTHERIDEA Stephenson, 1936

HAPLOCYTHERIDEA COLLEI Stephenson, n. sp.

Plate 28, figure 2

Carapace small, in side view elongate, highest at about midpoint. Dorsal margin gently arched, cardinal angles weak; ventral margin nearly straight in smaller right valve, convex in left. Anterior end broadly, obliquely rounded, often obscurely denticulate; posterior end narrower, bluntly truncated to rounded posteroventral angle. Surface comparatively smooth, with limited number of rather small pits. Hinge in right valve composed of terminal dental areas notched to form several cusps. Between and continuous with them is slightly lower line of fine crenulations, separated from dorsal margin by narrow groove. Notched hinge sockets well incised in left valve, joined by crenulate trench. Low bar above trench bounded dorsally by shallow depressed area.

Length (male), 0.61 mm.; height, 0.35 mm.; width, 0.28 mm.

Types: Holotype no. 2361, and paratypes nos. 2362–2364, from core at 6708–6710 feet, Magnolia Petroleum Company no. 1 H. B. Funchess, Jr., Jefferson County, Texas.

H. collei is smaller and more nearly subovate in side view than *H. israelskyi* Stephenson, n. sp., with which it occurs. The pitting is also somewhat more obscure.

Sexual dimorphism is obscurely distinguishable in this species, with the female slightly higher and more tumid than the male.

Named for Jack Colle, consulting geologist, Houston, Texas.

I have not seen this species in sediments younger than the lower portion of the *Marginulina* zone. It is described from material carrying *Marginulina howei* Garrett and Ellis.

HAPLOCYTHERIDEA ISRAELSKYI Stephenson, n. sp.

Plate 28, figure 1

Carapace low, tumid, in side view subpyriform, highest slightly anterior to middle. Left valve larger, overlapping around entire periphery. Dorsal margin nearly straight, sloping gently toward posterior, ventral margin straight to somewhat convex. Anterior end broadly rounded, usually armed with very short, fine spines. Posterior end obliquely truncated to narrowly rounded posteroventral angle. Surface rather smooth, bearing fairly numerous pits of moderate size and depth. Hinge structure typical for genus.

Length, 0.74 mm.; height, 0.41 mm.; width, 0.32 mm.

Types: Holotype no. 2365, from core at

5876–5880 feet, and paratypes nos. 2366, 2367, from core at 6034–6037 feet, Stanolind Oil and Gas Company no. B-2 Pipkin, Jefferson County, Texas.

The new species is somewhat similar to *H. blanpiedi* Stephenson (1936, pp. 701, 702, pl. 94, figs. 11, 12) but is a smaller, lower form, with fewer, less prominent pits.

Named for Merle C. Israelsky, Union Producing Company, Houston, Texas.

HAPLOCYTHERIDEA TEXANA
Stephenson, n. sp.
Plate 28, figure 14

Carapace tumid, in side view subovate, highest at middle. Left valve larger, overlapping around entire periphery, greatest overlap on dorsal and ventral sides. Dorsal margin gently arched, flattened along hinge line; ventral margin convex, more strongly so in left valve. Anterior end broadly, obliquely rounded; posterior end higher, more tumid, bluntly truncated to rounded posteroventral angle. General surface smooth, marked by moderate number of small, deep pits.

Length, 0.83 mm.; height, 0.54 mm.; width, 0.44 mm.

Type: Holotype no. 2368, from core at 6420–6422 feet, Magnolia Petroleum Company no. 1 H. B. Funchess, Jr., Jefferson County, Texas.

H. texana resembles *H. bassleri* Stephenson (= *Cytheridea subovata* Ulrich and Bassler, 1904, pp. 124, 125, pl. 37, figs. 1–8), which occurs in the Miocene of Maryland and Florida. The new species is smaller and shorter, and tends to be more prominently pitted.

Genus CYTHERETTA Müller, 1894
CYTHERETTA JEFFERSONENSIS
Stephenson, n. sp.
Plate 28, figure 13

Carapace in side view subrhomboidal, elongate, highest anteriorly. Dorsal margin slightly convex, subparallel to ventral margin, which is convex in left valve, somewhat sinuated in right valve. Anterior end broadly rounded; posterior narrower, subtriangular, often obscurely denticulate. More tumid portion of surface covered with fairly strong pits of moderate size, pitting becoming finer toward periphery. Central portion with low, rounded ridges arranged more or less horizontally, tending to coalesce around pits aligned between them. Hinge in right valve with strong anterior tooth, immediately in front of deep socket joining narrow groove extending to posterior tooth. In left valve, hinge with anterior socket, followed by elongate, knob-like tooth, merging with bar that continues to posterior socket. Marginal zones fairly broad, bearing numerous closely

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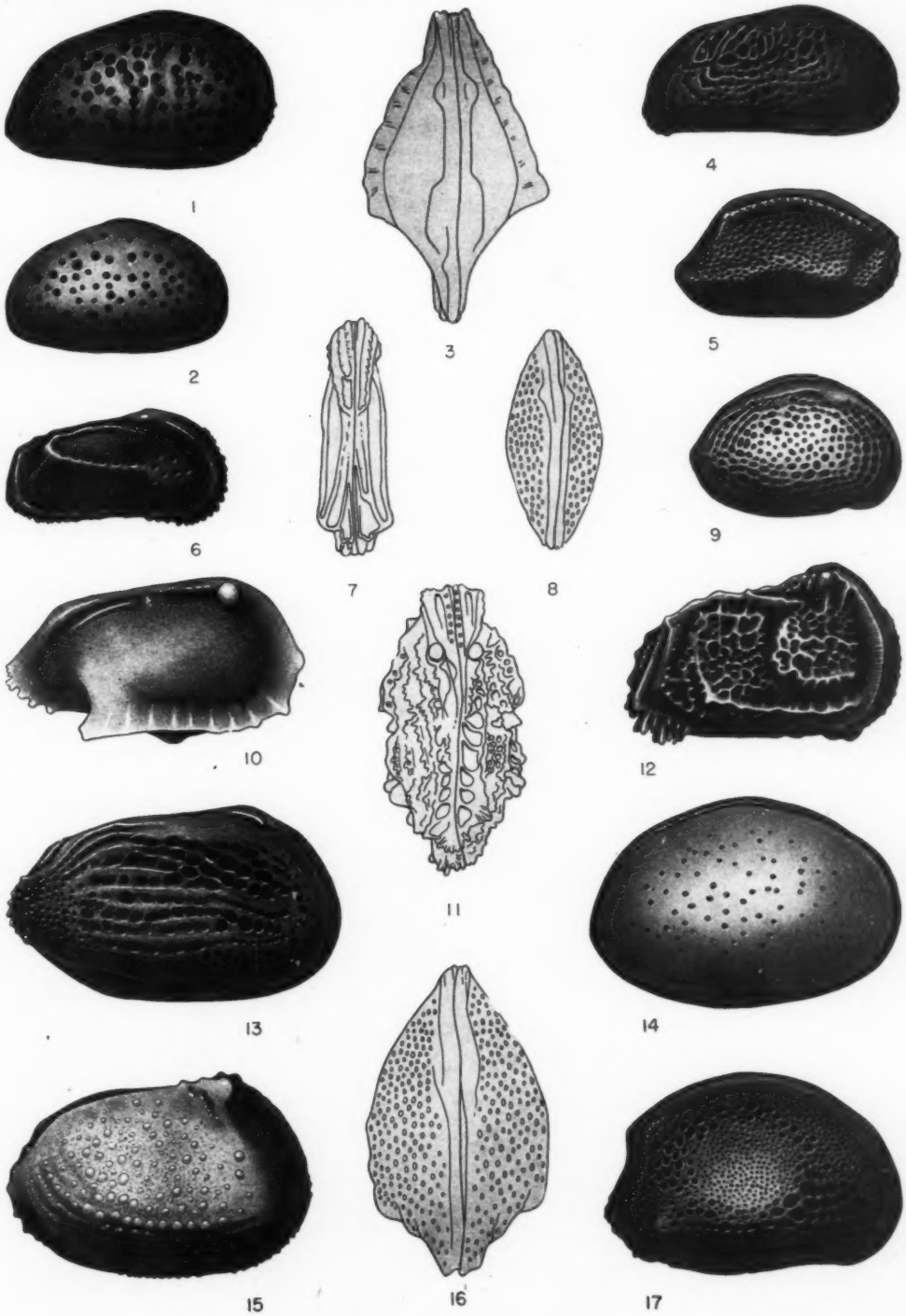
EXPLANATION OF PLATE 28

(All figures ×51)

FIGS. *1.—Haplocytheridea israelskyi* Stephenson, n. sp. Right valve view. *Heterostegina* zone. (p. 159)
2.—Haplocytheridea collei Stephenson, n. sp. Right valve view. *Marginulina howei zone.* (p. 159)
3, 10.—Alatacythere westi Stephenson, n. sp. *3*, Dorsal view, paratype; *10*, right valve, holotype. *Heterostegina* zone. (p. 158)
4.—Cytherideis rugosus Stephenson, n. sp. Right valve view. *Discorbis* zone. (p. 159)
5.—Bairdia? crumena Stephenson, n. sp. Right valve view. *Heterostegina* zone. (p. 156)
6, 7.—Cythereis macerta Stephenson, n. sp. *6*, Right valve view; *7*, dorsal view. *Heterostegina* zone. (p. 157)
8, 9.—Hemicythere amygdala Stephenson, n. sp. *8*, Dorsal view; *9*, right valve view. *Heterostegina* zone. (p. 158)
11, 12.—Cythereis hannai Stephenson, n. sp. *11*, Dorsal view; *12*, right valve view. *Marginulina idiomorpha* zone. (p. 157)
13.—Cytheretta jeffersonensis Stephenson, n. sp. Right valve view. *Discorbis* zone. (p. 160)
14.—Haplocytheridea texana Stephenson, n. sp. Right valve view. *Marginulina idiomorpha* zone. (p. 160)
15.—Cythereis verrucosus Stephenson, n. sp. Right valve view. *Heterostegina* zone. (p. 157)
16, 17.—Hemicythere saginata Stephenson, n. sp. *16*, Dorsal view; *17*, right valve view. *Heterostegina* zone. (p. 158)



Stephenson, Tertiary Ostracoda

UNIV. OF MICH.

spaced, rather irregular radial pore canals.

Length, 0.88 mm.; height, 0.52 mm.; width, 0.44 mm.

Type: Holotype no. 2369, from core at 5727–5732 feet, Stanolind Oil and Gas Company no. B-2 Pipkin, Jefferson County, Texas.

C. jeffersonensis bears some resemblance to *C. karlana* Howe and Pyeatt (see Howe and others, 1935, pp. 34, 35, pl. 1, figs. 30, 34; pl. 3, figs. 3, 4), from the Chipola Miocene of Florida. The Chipola species is larger, and has several rather prominent horizontal ridges which are lacking on the new species. *C. karlana* Howe and Pyeatt var. *choctawhatcheensis* Howe and Taylor (see Howe and others, 1935, p. 35, pl. 1, figs. 28, 29, 33), a rare form in the Choctawhatchee Miocene of Florida, seems closer to this species, but appears to have a much less prominent pattern of ridges and pits.

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MUSCLE SCAR PATTERNS ON SOME UPPER PALEOZOIC OSTRACODES

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ABSTRACT—Muscle scars have been found on the valves of Upper Paleozoic ostracodes of the genera *Bairdia*, *Healdia*, *Bythocypris*, *Waylandella*, *Seminolites*, *Cavellina*, and *Moorites*. The average size of an adductor muscle is approximately 200 microns in length and 50 microns in diameter. The muscle was made up of numerous closely packed fibers. Muscle scars are among the most important features for orientation because they generally occur in the anterior half of the carapace.

MUSCLE SCARS are commonly preserved on Mesozoic and Cenozoic ostracodes and are an important feature of the shell. Such scars, however, seem to be seldom preserved on Paleozoic ostracode valves for their occurrence has rarely been reported in the voluminous literature on Paleozoic ostracode faunas.

The discovery of well-preserved muscle scars on Pennsylvanian ostracodes from western Kentucky in 1938 initiated a search for scars in other collections. It was soon recognized that scars were preserved on many specimens that otherwise had been studied and classified. In fact, they are almost always present in certain genera but they have been completely overlooked because of methods of examination.

In searching for and studying muscle-scars two conditions are usually desirable; namely, high magnification and moist specimens. Ostracode valves are often studied with a magnification of 25 to 30. Few, if any, scars can be observed with such low magnification. A minimum magnification of 50 is essential for the discovery of most scars, but is insufficient for detailed study. I have found most successful a binocular with 144 magnification.

In addition to magnification higher than is normally used, it generally is necessary to moisten the specimen. Whether moisture is desirable or not depends, however, entirely on the nature of preservation. If the scar is so preserved that part of the shell remains over it then it is essential always to moisten the specimen but if the scar is preserved as a mold or cast then moisture often obliterates detail. One of the most successful methods used was to immerse the specimen in a clear oil of low specific gravity. Then by adjusting the light so that it would strike the specimen at the most favorable angle the details of muscle-scar patterns could be worked out. The presence of other internal structure such as marginal flanges and radial pore canals may also be discovered by the same technique.

Orientation of some Paleozoic ostracodes has been one of the most difficult problems in their study and description, and the one that has caused the most controversy. The position of the muscle scar is of primary importance in orientation. It is most commonly situated on the anterior part of the carapace; that is, anterior to a medial point between the greatest extension of the anterior and posterior ends. The scar may be slightly dorsal or ventral of midcarapace. Like most criteria as applied to orientation of ostracode valves, however, there are a few exceptions but these do not invalidate the general rule. The scar is posterior of midcarapace in *Polycope areolata* G. O. Sars, a living ostracode with an almost circular carapace. In a few of the Tertiary species the scar is also slightly posterior.

Scar patterns are also of some value in classification. Students of Tertiary and modern forms use the scar pattern as one feature of identification. The pattern is not sufficiently variable between species of the same genus to be of specific value in all cases. However, preservation in Paleozoic specimens is rarely perfect enough to make it possible to work out the secondary scar pattern in all of its details. Small secondary scars around the periphery are commonly so faint that they cannot be accurately counted and consequently the patterns preserved on

opposite valves of the same specimen may be slightly dissimilar.

Scars have been found on species of *Bairdia*, *Healdia*, *Bythocypris*, *Waylandella*, *Seminolites*, *Cavellina* and *Moorites*. Material has come from formations of the Mississippian and Pennsylvanian, mostly from the latter. The outstanding characteristic of the muscle scar patterns is their complexity as compared with those of modern genera. They are almost circular in outline and consist of numerous small secondary scars. The average diameter of the primary scar is approximately one-fifth to one-seventh the greatest height of the carapace. The secondary scars appear to be round but when well preserved and highly magnified they commonly show an imperfect hexagonal outline. They are very small, generally 3 to 10 microns in diameter and are most often found on molds but may be observed occasionally through the shell.

Muscle morphology.—Ostracode valves are connected at the dorsal margin by an elastic band that extends along the hinge. The elastic band may be reinforced by a tooth-and-socket structure that binds the valves together. The elastic band opens the valves in approximately the same manner as opening is accomplished in bivalved molluscs.

Ostracode valves are closed by a bundle of adductor muscle fibers that extend from one valve to the other, passing transversely through the body of the animal. The fibers are attached to the shell on slightly raised nodes or set in shallow pits. The points of attachment are generally in the anterior half of the shell, either anteroventral or anterodorsal of midcarapace.

In Paleozoic ostracodes each secondary scar is a small pit or node on the inside of the shell to which was attached an individual muscle fiber. There were as many as 46 fibers in some species of *Cavellina* or as few as three in *Moorites*.

The scar pattern in living species is more simple; that is, fewer secondary scars are present. The secondary scars tend also to be more widely separated than in Paleozoic species of the same genera. Very little has been written on the morphology of the muscles of living ostracodes. An examination of the adductor muscles of certain living fresh-water ostracodes shows that the central portion of the muscle, where it passes through the body of the animal, is commonly a single unit; whereas, the ends are divided into several units where attachment to the interior of the valve takes place. Apparently, the muscles in the upper Paleozoic genera which I have studied did not divide at the ends but continued from valve to valve as a single unit of the muscle fibers.

Scars have been found in three marine families represented in the Paleozoic; namely, Bairdiidae, Youngiellidae, and Cytherellidae. They also have been found in fresh-water genera of Cypridae.

The material from Muhlenberg County, Kentucky, was collected along the east side of Andres Run, northwest rectangle, Dunmore quadrangle, one mile south of South Union School, about 200 yards south of the "Y" road junction. Unweathered shale from above coal no. 9 was brought to the surface from a shallow mine shaft. This shale yields complete molds of the interiors of many ostracodes that show almost perfect muscle scars.

Acknowledgment is made of the aid Mr. Harry Ford gave in the study of certain specimens collected from Pennsylvanian shales above Kentucky coal no. 9. Special thanks are also due to Dr. Charles Summerson, University of Illinois, who discovered the scars on two species of *Bairdia* which he collected from the lower Pennsylvanian of Tennessee.

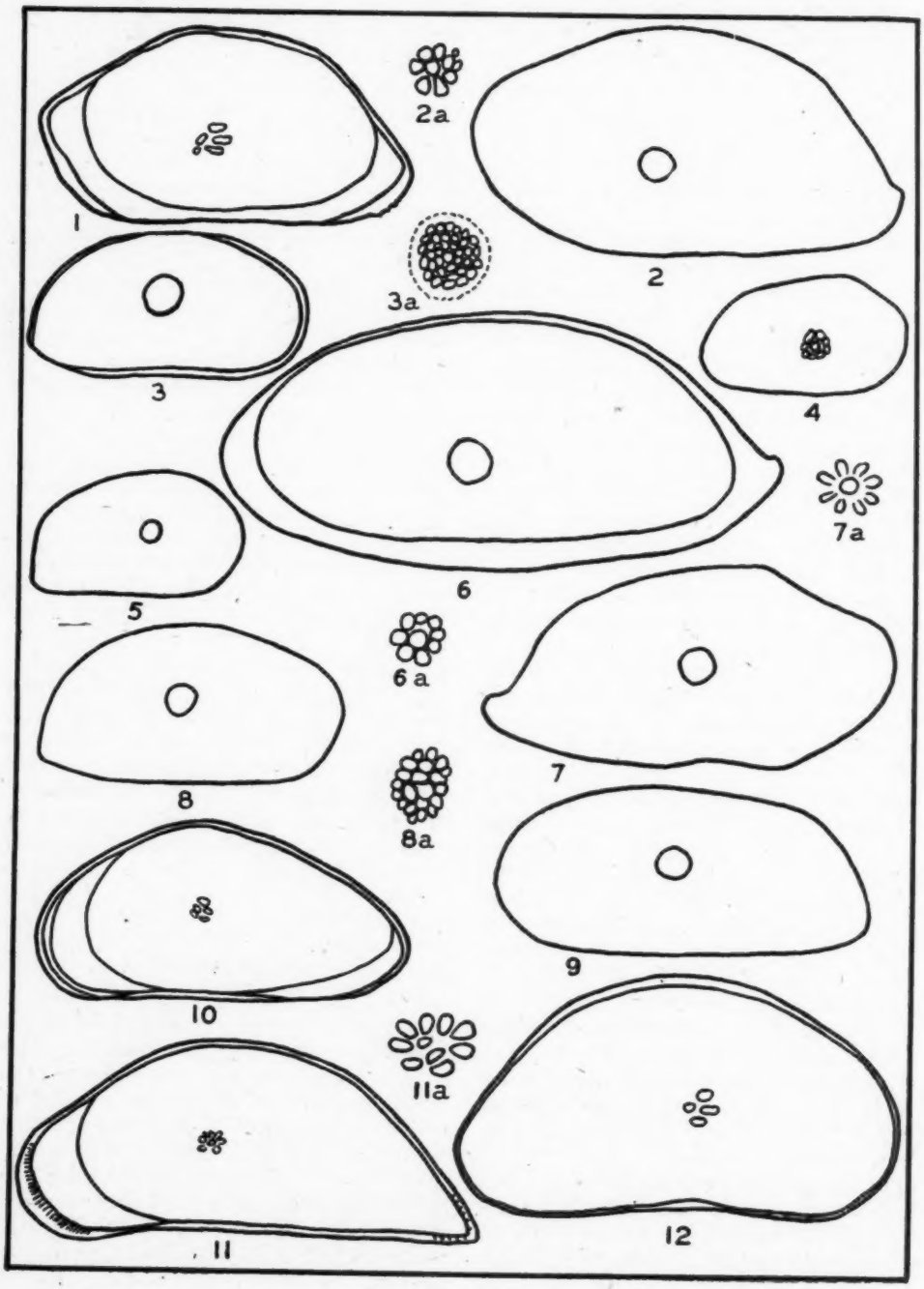
SYSTEMATIC DESCRIPTIONS

Order OSTRACODA Latrielle

Family BAIRDIIDAE Sars

Genus BAIRDIA McCoy, 1844

A study of living forms of *Bairdia* makes it possible to correctly orient fossil species of this genus without referring to the muscle scars. The more acuminate end in lateral view is posterior, the greatest height is near or slightly anterior of middle, and the left valve is the largest, overlapping the right. The muscle scar pattern in modern species generally consists of five slightly elongate-ovate scars situated in a position immediately anteroventral of midcarapace. The long axis of each scar is roughly parallel to the long axis of the shell. The scars are closely grouped, although generally they do



FIGURES *1–12*

not touch each other. The individual scars are approximately the same size with the exception of one which is about half the size of the other four.

The scar pattern in upper Paleozoic species is more circular in general outline, and is made up of more numerous and more closely packed secondary scars than those found in living species. The most common arrangement consists of a central scar surrounded by 6 to 8 others. In all the internal molds of my collection the secondary scars are minute pits. In the original shell the muscle must have been attached to points slightly raised above the inner shell surface.

Bairdia has had a long geological history, ranging from Ordovician to Recent. It is still a common animal widely distributed in all oceans where the water is moderately warm and shallow.

BAIRDIA INFLATA (Norman)
Figure 1

Bairdia inflata (Norman), 1938, An account of the Crustacea of Norway, vol. 9, pl. 30, fig. 2.

Muscle scar pattern typical of the genus, composed of five elongate-elliptical scars directly in front of midcarapace. Each secondary scar is a raised area on interior of shell to which was attached a muscle fiber. Fibers probably coalesced short distances from points of attachment and passed through animal as single bundle.

Recent, coast of Norway.

BAIRDIA POMPILIOIDES Harlton
Figures 7, 7a

Bairdia pompilioides Harlton, 1938, Jour. Paleontology, vol. 2, no. 2, pl. 21, fig. 13.

An almost perfectly preserved pattern consists of eight slightly ovate secondary scars surrounding a circular medial scar. This pattern is remarkably similar to that found in some species of *Macrocypris* (fig. 11). The scar is on a specimen that measures 0.90 mm. in length and 0.43 mm. in height. The diameter of the scar is about 75 microns.

Trivoli cyclothem, Pennsylvanian, Clark County, Illinois.

BAIRDIA BEEDEI Ulrich and Bassler
Figure 4

Bairdia beedei Ulrich and Bassler, Kellett, 1934, Jour. Paleontology, vol. 8, p. 123, pl. 14, fig. 2.

Muscle-scar pattern shown on photograph by Kellett is very similar to that of *B. pompilioides*. It appears to consist of eight secondary scars arranged in a ring around central scar.

Mid-Pennsylvanian to Permian.

EXPLANATION OF FIGURES 1–12

FIGS. *1*—*Bairdia inflata* (Norman). Interior right valve, ×46. Recent, coast of Norway and British Isles. After G. O. Sars. (p. 165)

2, 2a—*Bairdia* aff. *auricula* Knight. *2*, Mold of interior of left valve, ×64. *2a*, Muscle scar, ×130. Lower Pennsylvanian, Tenn. (p. 166)

3, 3a, 8, 8a—*Bythocypris pediformis* Knight. *3*, Exterior of right valve, ×64. *3a*, Muscle scar, ×125. Gimlet cyclothem, Illinois. *8*, Exterior of right valve, ×64. *8a*, Muscle scar, ×130. (p. 168)

4—*Bairdia beedei* Ulrich and Bassler. Mold of interior of right valve. Wreford formation, Permian, ×20. After Kellett. (p. 165)

5—*Bythocypris* aff. *procera* Coryell and Billings. Exterior of right valve. Muscle scar very faint, details not discernible. Gimlet cyclothem, Ill. (p. 168)

6, 6a—*Bairdia* sp. 6, mold of interior of left valve, ×64. *6a*, Muscle scar, ×90. Lower Pennsylvanian, Tenn. (p. 166)

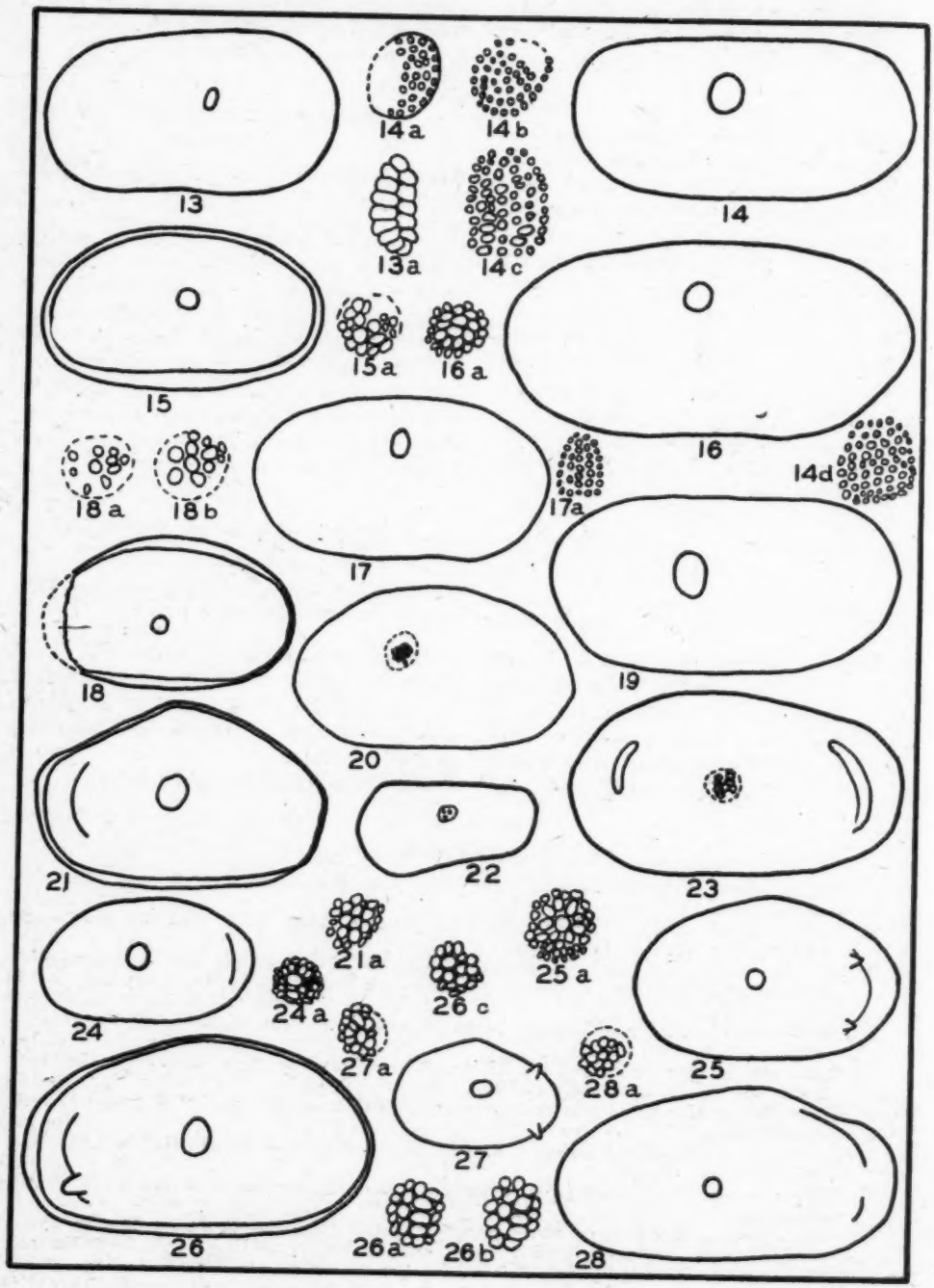
7, 7a—*Bairdia pompilioides* Harlton. *7*, Exterior right valve, ×64. *7a*, Muscle scar, ×120. Trivoli cyclothem, Illinois. (p. 165)

9—*Bythocypris* sp. Mold of left valve. Muscle scar faint. From shale over coal no. 9, Western Kentucky.

10—*Pontocypris trigonella* Sars. Exterior of left valve. Larger right valve showing around margin, muscle scar and marginal flange outlines showing through shell. Approximately, ×75. Recent, coasts of Norway, British Isles, and Mediterranean. After G. O. Sars.

11—*Macrocypris minna* (Baird). Exterior left valve, ×20. Recent, coast of Norway. After G. O. Sars.

12—*Bythocypris bosquetina* Brady. Exterior right valve. Approximately, ×60. Recent, Atlantic, Mediterranean. After G. O. Sars.



FIGURES *13–28*

BAIRDIA aff. B. AURICULA Knight
Figures 2, 2a

Bairdia auricula Knight, 1938, Jour. Paleontology, vol. 2, no. 4, pl. 43, figs. 3a–b, p. 320.

Muscle scar situated anteroventral of mid-carapace 40 microns in diameter. Central scar surrounded by six others of equal size. Two small, very faint scar impressions occur along posterodorsal outer margin. Some secondary scars distinctly wedge-shaped, the most cuneate end pointing toward central scar.

The scar is preserved on the mold of a left valve that measures 0.90 mm. in length and 0.50 mm. in height. The specimen is probably conspecific with *B. auricula* Knight. Lower Anderson formation (approximately Magoffin shale zone, Pennsylvanian) Petros section, Frozenhead Mountain, Morgan County, Tenn.

BAIRDIA sp.
Figures 6, 6a

An almost perfectly preserved muscle scar was found on a left valve mold of an undescribed species of *Bairdia*. The valve measures 1.22 mm. in length and 0.56 mm. in height. Muscle scar 100 microns in diameter, anteroventral of midcarapace, consists of eight circular secondary scars surrounding slightly larger medial scar.

Lower Anderson formation (approximately Magoffin shale zone, Pennsylvanian) Petros section, Frozenhead Mountain, Morgan County, Tenn.

Genus BYTHOCYPRIS Brady, 1888

Individuals belonging to this genus are easily misoriented because of lack of diagnostic surface features. The muscle scar pattern in living species is almost identical

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EXPLANATION OF FIGURES 13–28

FIGS. *13*, *13a—Cytherella abyssorum* G. O. Sars. *13*, Exterior right valve. Approximately ×42. *13a*, Muscle scar, ×160. After Sars. Recent, coast of Norway.

14, *14a–d—Cavellina* sp. 14, Mold of interior of left valve, ×64. 14 *a–b*, Muscle scars of left and right valves respectively, ×130. *14c*, Almost perfectly preserved scar on mold on left valve of a second specimen, ×180. *14d*, Scar on mold of right valve of a third specimen, ×180. (p. 170)

15, *15a*, *18*, *18a–b—Bythocypris tomlinsoni* Harlton. *15*, Exterior of right valve, ×64. *15a*, Muscle-scar ×180. Trivoli cyclothem, Stark Co. Illinois, *18*, Exterior right valve, ×64. *18a–b*, Muscle scars, left and right valves, ×250. (p. 168)

16, *16a—Cavellina* aff. *expansa* Bradfield. *16*, Exterior of left valve, ×64. *16a*, Muscle scar, ×130. Liverpool cyclothem, La Salle Co., Illinois.

17, *17a—Cavellina missouriensis* (Knight). *17*, Mold of left valve, ×64. *17a*, Muscle-scar, ×120. From shale above coal no. 9, Pennsylvanian, Western Kentucky. (p. 170)

19—Cavellina glandella (Whitfield). Mold of left valve, ×20. Salem limestone. Univ. of Illinois, plesiotype M-382. (p. 170)

20—Cavellina savagei (Geis). Mold of interior of left valve. Paratype no. M-377. Salem limestone, Indiana. (p. 170)

21–21a—Healdia simplex Roundy. *21*, Exterior of right valve, ×64. *21a*, Muscle scar, ×130. (p. 170)

22—Moorites minutus (Warthin). Exterior of right valve, ×80. (after Ford). Shale above coal no. 9, Pennsylvanian, western Kentucky. (p. 171)

23—Seminolites sp. Exterior of left valve. Scar pattern poorly preserved. Gimlet cyclothem, Pennsylvanian, Illinois. (p. 171)

24, *24a—Healdia nucleolata* Knight. *24*, Exterior of left valve, ×64. *24a*, Muscle scar, ×150. Gimlet cyclothem, Pennsylvanian, Illinois. (p. 169)

25, *25a—Healdia leguminoidea* Knight. 25, Exterior left valve, ×64. *25a*, Muscle scar, ×250. Gimlet cyclothem, Pennsylvanian, Illinois. (p. 169)

26, *26a–c—Waylandella* sp. *26*, Mold of right valve, ×64. *26a–b*, Muscle-scars on left and right valves. *26c*, Muscle scar on right valve of a second specimen, ×120. Liverpool cyclothem, Pennsylvanian, Illinois. (p. 171)

27, *27a—Healdia limacoidea* Knight. *27*, Exterior of left valve, ×64. *27a*, Muscle scar, ×120. Gimlet cyclothem, Illinois. (p. 169)

28, *28a—Healdia longa* Knight. *28*, Exterior of left valve ×64. *28a*, Muscle-scar ×200. Gimlet cyclothem, Pennsylvanian Illinois. (p. 169)

with that found in living forms of *Bairdia*. There are four or five slightly raised, elongate-ovate, scars situated immediately anteroventral of midcarapace. The long axis of each scar is approximately parallel to the long axis of the shell. The scars are closely bunched but do not touch each other. A secondary scar in a shell 2 mm. long measured 100 microns in length and 40 microns in width.

Scar patterns have been found on three of the common fossil species, *B. pediformis*, *B. procera*, and *B. tomlinsoni*. The pattern is almost a perfect circle, on the inside of which are many very minute secondary scars and it is not at all similar to that found in modern forms. The pattern in fossil species of *Bythocypris* is more similar to that of fossil *Cavellina* than it is to the pattern in living forms of *Bythocypris*. This strongly suggests that the two genera are closely related and may have had a common ancestor in early Ordovician time.

In *Bythocypris* the left valve is larger and overlaps the right all around. The anterior end is more broadly rounded than the posterior. The greatest extension of the posterior end is below the median line. The greatest height is medial; the greatest thickness is posterior to medial.

Bythocypris has had a long geological history, ranging from Ordovician to Recent, reaching a point of maximum development in the Pennsylvanian.

BYTHOCYPRIS PEDIFORMIS Knight
Figures 3, 3a, 8, 8a

Bythocypris pediformis Knight, 1928, Jour. Paleontology, vol. 2, p. 326, pl. 44, figs. 3a–c.

Muscle-scar pattern circular, diameter one-fourth to one-fifth greatest height of carapace, situated immediately anterior of midcarapace, composed of numerous very small round crowded scars. Secondary scars more or less concentrically arranged in three rows.

In what appears to be an almost perfectly preserved pattern (fig. 3a) there is a total of 37 secondary scars surrounding a central one in successive rows of 7, 13, and 16. Another scar (fig. 8a) has only 21 secondary scars, but they are arranged in circular rows and probably represent an incomplete pattern.

The specimen shown in figure 3 measures 0.60 mm. in length and 0.31 mm. in height. The scar is 85 microns in diameter. The specimen shown in figure 8 measures 0.68 mm. in length and 0.35 mm. in height. The incomplete scar has a diameter of 60 microns.

Gimlet cyclothem, Pennsylvanian; Clark Branch, sec. 34, T. 9 N., R. 52, Illinois.

BYTHOCYPRIS aff. B. PROCERA Coryell and Billings
Figure 5

Bythocypris procera Coryell and Billings, 1932, Am. Midland Naturalist vol. 13, no. 4, pl. 17, fig. 12.

Muscle-scar pattern circular, diameter approximately one-fifth greatest height of carapace, situated anterior of median point. Secondary scars are so poorly preserved that details of pattern can not be determined. The scar is very small, about 40 microns in diameter, in a specimen that measures 0.47 mm. in length and 0.28 mm. in height.

Pennsylvania shale overlying no. 9 coal, Muhlenberg County, Kentucky.

BYTHOCYPRIS TOMLINSONI Harlton
Figures 15, 15a, 18, 18a, b

Bythocypris tomlinsoni Harlton, 1929, Am. Jour. Sci. ser. 5, vol. 18, pl. 2, figs. 17 a–e.

Two specimens have been found which show partial to complete scar patterns on both valves. Pattern composed of approximately 26 secondary scars in roughly concentric bands. One or two comparatively large central scars are surrounded by band of about 9 slightly smaller scars. Outer bands consist of minute scars approximately one-third size of inner group.

Trivoli cyclothem, Pennsylvanian, Clark County, Illinois.

Genus MACROCYPRIS Brady, 1866

No muscle scars have been found on fossil species. The pattern of *M. minna* (Baird) (figs. 11, 11a), a modern form, is shown for the purpose of comparing it with selected genera. The pattern is very similar to that found in fossil species of *Bairdia*. It consists of a central scar surrounded by several others arranged in a single row. The scars have been reported by Sars (p. 58) as

"numerous and arranged so as to form together a circular area." The patterns of *Bairdia* and *Macrocypris* are sufficiently similar to justify placing the two genera in the same family.

Genus PONTOCYPRIS G. O. Sars, 1865

The scar pattern of *P. trigonella* Sars (fig. 10) is shown because of its similarity to the patterns on modern species of *Bairdia* and *Bythocypris*. Fossil scars are unknown.

Genus HEALDIA Roundy, 1926

Muscle-scar patterns have been found on 5 species of *Healdia*. They are more common and better preserved in this genus than in any other. The pattern consists of a circle enclosing numerous secondary scars closely packed together. The secondary scars are arranged more or less in concentric bands, the smaller scars in the outer band and the larger ones on the inside. The number of secondary scars is variable, as many as 35 have been found.

The diameter of the muscle-scar circle ranges from 0.25 to 0.30 of the greatest height of the carapace. In most species the scar is situated slightly anterior and usually anteroventral of midcarapace. In *H. limacoidea* the scar is slightly posterior of midcarapace.

The position of the scar verifies the generally accepted orientation of *Healdia*. The ridge or spines are posterior, the greatest height is medial to slightly posterior, and the left valve is larger than the right.

The similarity of the muscle scar of *Healdia* to those of *Bairdia* and *Bythocypris* suggests that the genus should be classified in the family Bairdiidae and not placed in a separate family as has occasionally been done.

HEALDIA NUCLEOLATA Knight
Figures 24, 24a

Healdia nucleolata Knight, 1928, Jour. Paleontology, vol. 2, no. 4, p. 329, pl. 44, figs. 4a–e.

Muscle scar large, circular, situated slightly anterodorsal of midpoint; diameter of muscle scar approximately one-fourth greatest height of carapace; scar pattern made up of approximately 32 small, round to ovate scars, roughly arranged in two concentric bands which surround large central scar; outer band consists of 17 small scars enclosing approximately 15 others imperfectly arranged.

The scar has a diameter of 42 microns and occurs in a shell 0.46 mm. in length and 0.21 mm. in height.

Gimlet cyclothem, Pennsylvanian; Clark Branch, sec. 34, T. 9 N., R. 5 E., Illinois.

HEALDIA LEGUMINOIDEA Knight
Figures 25, 25a

Healdia leguminoidea Knight, 1938, Jour. Paleontology, vol. 2, no. 4, p. 332, pl. 44, figs. 7a–b.

Muscle scar small, circular, situated slightly anterior of midcarapace; diameter of scar about one-fourth greatest height of carapace; scar pattern of 35 round to ovate scars, 18 in marginal band, eight in inner band, one relatively large circular central scar; 8 secondary scars occur along ventral border, may represent incomplete third band.

Diameter of scar 35 microns; shell length 0.56 mm., height 0.33 mm.

Gimlet cyclothem, Pennsylvanian, Clark Branch, sec. 34, T. 9 N., R. 5 E., Illinois.

HEALDIA LIMACOIDEA Knight
Figures 27, 27a

Healdia limacoidea Knight, 1928, Jour. Paleontology, vol. 2, no. 4, p. 333, pl. 44, figs. 5a–c.

Muscle scar circular, situated almost in center of the carapace, slightly posterior of greatest height; diameter of scar approximately one-fourth greatest height of carapace. Scar pattern consists of many closely packed, small, round to ovate scars. Nineteen secondary scars are preserved. A complete pattern would probably show three concentric bands.

Diameter of scar 50 microns; shell length 0.35 mm., height 0.23 mm.

Gimlet cyclothem, Pennsylvanian, Clark Branch, sec. 34, T. 9 N., R. 5 E., Illinois.

HEALDIA LONGA Knight
Figures 28, 28a

Healdia longa Knight, 1928, Jour. Paleontology, vol. no. 4, p. 332, pl. 44, figs. 6a–c.

Muscle scar small, circular, situated anteroventral of midcarapace; diameter equal to approximately one-tenth greatest height of carapace; secondary scars closely packed,

outer band of 12 or more small scars surrounding 10 larger central scars.

Diameter of scar 60 microns; shell length 0.62 mm., height 0.46 mm.

Gimlet cyclothem, Pennsylvanian, Clark Branch, sec. 34, T. 9 N., R. 5 E., Illinois.

HEALDIA SIMPLEX Roundy
Figures 21, 21a

Healdia simplex Roundy, 1926, U. S. Geol. Survey, Prof. Paper, 146, p. 8, pl. 1, figs. 11a–c.

Muscle scar round, 20 or more secondary scars; diameter about one-fifth greatest height of carapace.

Gimlet cyclothem, Illinois.

Genus CAVELLINA Coryell 1928

Muscle scar circular to ovate, of numerous small secondary scars in two or more concentric rows. Secondary scars round to ovate, crowded together. Diameter of scar from one-fifth to one-eighth greatest height of carapace, situated well anterior and dorsal of midcarapace.

Kellett (1935) has shown that Carboniferous species of *Cytherella* are the males of *Cavellina* and suggests that the name *Cavellina* be used for these upper Paleozoic forms. Kellett considered the shorter posterior vertical ridge on the interior of valves of females of *Cytherella* from Mesozoic and Cenozoic strata of sufficient significance to separate them from the longer ridged Carboniferous species. The muscle-scar pattern of *Cytherella abyssorum* (fig. 13a) as drawn by Sars differs greatly from the patterns found on Carboniferous cavellinids. The differences appear sufficient to justify Kellett's disposal of the Paleozoic cytherellids but almost as much difference exists between the muscle-scar patterns of Paleozoic and Recent species of *Bairdia*.

CAVELLINA MISSOURIENSIS (Knight)
Figures 17, 17a

Cytherella missouriensis Knight, 1928, Jour. Paleontology, vol. 2, no. 4, p. 334, pl. 44, figs. 8a–i.

Muscle scar ovate, diameter about one-fifth greatest height of carapace, anterodorsal of midcarapace. Secondary scars very small, arranged in approximately 5 vertical rows.

Diameter of scar 50–60 microns; shell length 0.70 mm., height 0.35 mm.

Marine shale above coal no. 9, Muhlenberg County, Kentucky.

CAVELLINA GLANDELLA (Whitfield)
Figure 19

Cavellina glandella (Whitfield), Geis, 1932, Jour. Paleontology, vol. 4, no. 2, p. 186, pl. 26, figs. 9a–d.

Scar pattern not well preserved on specimen described by Geis. Scar large, approximately one-fourth greatest height of carapace, considerably anterior of midcarapace.

Salem limestone, Indiana. University of Illinois, plesiotype no. M 382.

CAVELLINA SAVAGEI (Geis)
Figure 20

Cytherella savagei Geis, 1932, Jour. Paleontology, vol. 6, no. 2, p. 184, pl. 26, figs. 6a–f.

Muscle scar anterodorsal of midcarapace. A few secondary scars faintly preserved in central area, probably arranged in concentric bands. Diameter of scar about one-fifth greatest height of carapace.

Salem limestone, Indiana. University of Illinois, paratype, no. M 377.

CAVELLINA MUHLENBERGENSIS Scott, n. sp.
Figures 14, 14a–d

Carapace elongate, subrectangular; ends rounded, dorsal and ventral margins approximately parallel; posterior end slightly inflated in dorsal view, anterior end cuneate; inner posterior ridge strongly developed, extending from center three fourths of way to dorsum; posterior depression deepest in ventral third; muscle scar large, circular to gently ovate, anterodorsal of midcarapace; approximately 56 secondary scars in slightly imperfect concentric bands, concentric arrangement more perfect in some specimens than in others.

Diameter of scar 75 microns; shell length 0.75 mm., height 0.35 mm. University of Illinois holotype ×1315, paratype ×1317. Marine shale above coal no. 9, Muhlenberg County, Kentucky.

Genus SEMINOLITES Coryell 1928
Figure 23

Only a single valve of an undescribed species of this genus has been found which shows a muscle scar. The scar is anterior of midcarapace, slightly posterior of the greatest height of valve. Approximately 10 secondary scars are preserved in two vertical rows. This probably very incomplete scar shows the position of its occurrence on *Seminolites*.

Shell length, 0.72 mm.; height, 0.39 mm.

Genus WAYLANDELLA Coryell and Billings, 1932

This genus was established for bythocyprid ostracodes that have spines near the posterior end. The genotype, *W. spinosa*, was described as having "two spines . . . near the posterior margin of each valve." There are some specimens from the Trivoli cyclothem that possess only one spine, but in all other details conform to *Waylandella*. The difference in number of spines can hardly be considered of generic importance. The muscle-scar pattern of an undescribed species of this genus was found on two specimens, on both valves of one and on the right valve of the other.

WAYLANDELLA sp.
Figures 26, 26a–c

Muscle scar large, circular; situated in almost exact center of carapace; diameter of scar one-seventh greatest height of carapace; scar pattern of about 20 round to ovate secondary scars in roughly vertical rows that are gently arched with convex portion anterior. Shell length 0.76 mm., height 0.43 mm.; diameter of scar 60 microns.

Liverpool cyclothem, Pennsylvanian, La Salle County, Illinois.

MANUSCRIPT RECEIVED SEPTEMBER 9, 1942.

Family YOUNGIELLIDAE Kellett
Genus MOORITES Coryell and Billings
MOORITES CONVERGENS (Bradfield)
Figure 22

Youngiella convergens Bradfield, 1935, Bulls. Am. Paleontology, vol. 22, pl. 4, p. 72, figs. 16a–b.

Muscle scar small, ovate, slightly anterior but considerably above midcarapace. Long axis parallel to long axis of carapace. Secondary scars three, two at top and one at base; greatest length of scar about one-ninth greatest length of carapace.

Shell length, 0.38 mm., height, 0.21 mm.; diameter of scar 30 microns.

Marine shale above coal no. 9, Muhlenberg County, Kentucky.

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NEW WEST AMERICAN SPECIES OF THE FORAMINIFERAL GENUS ELPHIDIUM

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ABSTRACT—Specimens heretofore called *Elphidium crispum* from the Pleistocene and Recent of the West Coast of North America are assigned to three new species and three new subspecies. They are described and separated by statistical methods after a study of four samples of 200 specimens each. *Elphidium crispum* (Linné), 1758, based on poor figures, is of doubtful taxonomic validity. *Elphidium macellum* (Fichtel and Moll), the genotype, which is figured and compared with the West Coast species, is related to but not conspecific with any of them. By thus narrowly defining the taxonomic units, one can demonstrate that the various species have a limited geographic distribution. The larger species are found in cold water and the smaller species in warm water.

INTRODUCTION

As more careful systematic, paleontologic, and stratigraphic work is carried on, it becomes increasingly evident that statistical or mathematical analysis of species is a valuable adjunct to verbal description and illustration of specimens. Tolman (1933) made the following farsighted observation:

> The *Elphidium crispum* group is peculiarly suitable for statistical analysis, and it is interesting to note in our West Coast representatives how such a study shows the very sharply limited geographical range of the two varieties present. It is the writer's opinion that if such statistical methods were more widely applied, finely split species of *Foraminifera* would always be found to have localized geographic and ecologic range, while more generalized species, for instance those with few chambers and no ornamentation, would have a considerably wider range.

This statistical study of some Recent and one Pleistocene species of *Elphidium* of the West Coast of North America confirms Tolman's belief. Specimens long called *Elphidium crispum* are allocated here to three species and three subspecies having restricted geographic distributions. The demonstration of this conclusion constitutes the major contribution of this paper.

The question naturally arises as to why so many different eastern Pacific specimens have been called *Elphidium crispum*, as was done by Cushman and Grant (1927), Cushman and Valentine (1930), Martin (1932), Cushman (1939), Cushman and McCulloch (1940). The following is a likely explanation: Linné (1758, p. 709) gave the locality of *Nautilus crispus* as the Mediterranean Sea. He referred to figures by Gualtieri and Plancus. These illustrations are poor and so inaccurate that no idea of the exact nature of *Nautilus crispus* can be gained. Linné's type material of this species has not been found. It would seem that this is a *species dubium*. Contemporary students of the Foraminifera have been using Brady's or other workers' concepts of *Elphidium crispum*.

Another species which closely resembles those on the West Coast of North America is *Nautilus macellus* described by Fichtel and Moll (1803, pp. 66–68) from the Mediterranean Sea. This species by subsequent designation (Galloway 1933, p. 269) became the genotype of the genus *Elphidium*. Here figured (pl. 29, figs. 6, 7) is a topotype from Rimini, Italy. These figures indicate that the specimens from western America reported upon are assigned to the correct genus.

ACKNOWLEDGMENTS

This study was suggested and supervised by H. G. Schenck. The statistical work was done under the direction of F. W. Weymouth without whose assistance the problems could not have been solved. H. E. Thalmann called attention to several relevant papers. C. V. Taylor made available the literature in his personal library. A. Myra Keen offered advice in statistics and taxonomy. Earl H. Myers and Manley L. Natland generously gave information and donated specimens of *Elphidium*. Lois T.

Martin released for study and use, illustrations and specimens. Trevor Kincaid and W. H. Holman supplied samples. The figures on plate 29 are the work of Margaret Hughes, and the charts and correlation tables were drafted by Mrs. Carl F. Janish. To all these the writer expresses his sincere gratitude.

METHODS

Samples were studied in detail from three localities along the intertidal region of the West Coast of North America and from a fourth locality in the lower Pleistocene, Santa Barbara formation, Santa Barbara, California. Each sample contained 200 specimens which were perfect enough to be measured. For brevity the following symbols are used to indicate these localities:

U.—Punta Peñasco, Sonora, Mexico. *Elphidium excubitor, Elphidium concinnum.*

S.—Santa Barbara formation (lower Pleistocene), Santa Barbara, California. *Elphidium fax barbarense.*

M.—Mussel Point, Monterey Bay, California. *Elphidium fax pingue.*

D.—Dallas Bank, Straits of Juan de Fuca, Washington. *Elphidium fax fax.*

Procedure for measuring and cataloguing each specimen was simple. A monocular compound microscope with micrometer eyepiece was used for three measurements: greater diameter, lesser diameter, and thickness (see figs. 1a, b). Counts were made of the number of chambers in the outer whorl. Data for each specimen were entered on a numbered card and the specimens were filed individually under corresponding numbers for further reference.

Breadth of the outer whorl in these involute, nautiloid forms can be obtained from the ratio of lesser diameter to greater diameter. This ration is nearly the same for specimens in all four samples; about 0.885. The measurements of lesser and greater diameters were taken 180° or one-half of a whorl apart. Assuming that the increase is proportional, for 360° one would expect a ratio of 0.783 or 1:1.3. This is a common ratio in Foraminifera as well as in ammonites and other invertebrates having a flat spiral form (Thompson, 1942, pp. 796, 858). This ratio of breadth in successive whorls was approximately the same in all species and subspecies of *Elphidium* studied.

The statistical methods used are standard and are explained in any general textbook on the subject. For convenience, however, a glossary of symbols is given.

Meaning of the symbols employed:

$\bar{x}$, $\bar{y}$—the means of x and of y.
r_{xy}—coefficient of correlation.
b_{xy} (---)—regression coefficient of x on y.
b_{yx} (—)—regression coefficient of y on x.
Sx—standard deviation of x.
R—ratio.
S_R—standard deviation of the ratio.
k—relative deviate.
P—probability.
SE—standard error.
Max—maximum.
Min—minimum.
L.D.—lesser diameter.
G.D.—greater diameter.
Th.—thickness.
Ch.n.—chamber number of outer whorl.

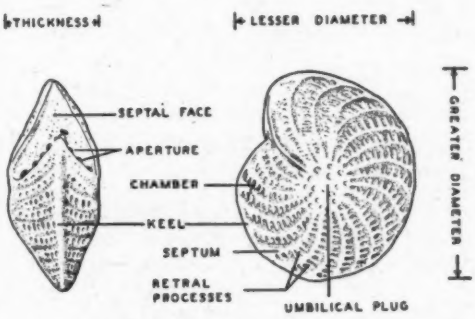


FIG. 1—Dimensions measured and morphologic features of *Elphidium*. *a*, Apertural view. *b*, Side view.

The holotypes of new species and subspecies are deposited in the Stanford University Paleontological Type Collection.

The figured specimens are deposited in the Stanford University Paleontological Type Collection. Paratypes have been sent to the following institutions: U. S. National Museum; California Academy of Sciences; University of California, Museum of Paleontology; Cushman Laboratory for Foraminiferal Research; San Diego Society of Natural History; University of California at Los Angeles; American Museum of Natural History; Bureau of Economic Geology, University of Texas; Paleontological Research Institution, Ithaca, New York; British Museum (Natural History).

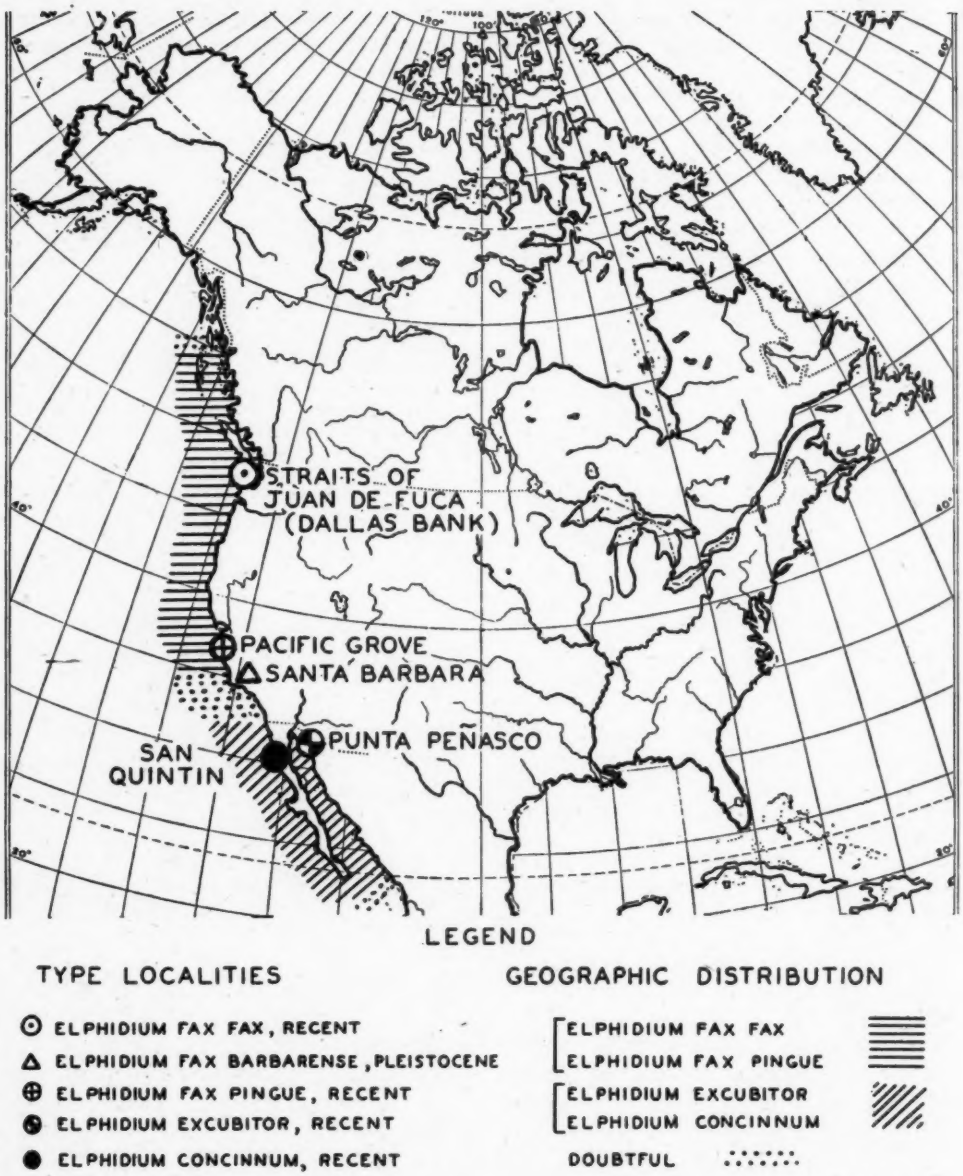


FIG. 2—Outline map showing type localities and geographic distribution of new species and subspecies of *Elphidium* on the Pacific Coast of North America.

GEOGRAPHIC DISTRIBUTION

Geographic study of the Recent species of *Elphidium* reveals interesting comparisons in distribution and maximum size of specimens to temperature and latitude. The species are all closely allied genetically and ecologically. All samples were from the intertidal zone of the Pacific Coast of North America, and the morphologic resemblance of the representatives of the several species is apparent and striking.

Cushman and Grant (1927, p. 74) noted differences in size in the specimens of *Elphidium* found in the warm waters off Mexico as compared to the cold-water specimens found at Queen Charlotte Islands, British Columbia. They identified specimens from both localities as *Elphidium crispum*. Tolman (1933) was the first to observe that there is a distinct break in the distribution of *Elphidium "crispum"* just north and south of Point Concepcion. Other references to this species on the West Coast have been casual.

The distribution map (fig. 2) shows that there are two southern species, *Elphidium excubitor* and *E. concinnum*, whose geographic range is from San Diego south. To the north of Point Concepcion is *E. fax pingue*, which has its southern limit at San Luis Bay, California. Somewhere between Moss Beach, San Mateo Co., California and Puget Sound this subspecies is replaced by *E. fax fax*.

The exact southern limit of *E. concinnum* and *E. excubitor* and the northern limit of *E. fax fax* are not known and are indicated by dotted lines on the map. The dotted area from Point Concepcion to San Diego separating the southern and northern species is also indefinite. Natland (personal communication) states that after much sampling *E. "crispum"* was not found along the beaches of Orange, Los Angeles, or Ventura Counties, but was present at San Diego. Rankin (1931) did not report *E. "crispum"* from Newport Lagoon, Orange County, California. Cushman and Valentine (1930, p. 21), however, reported this species from the Channel Islands of California, as did Tolman (1933) from the Santa Barbara Channel.

As only samples from the intertidal zone were carefully studied and identified, the depth to which these species live is not known. A sample from near Catalina Island at a depth of 500 feet contained *E. "crispum,"* but on careful examination these shells appear to be more closely related to *E. fax barbarense* than to any Recent species living in adjacent areas. Natland (personal communication) believes *Elphidium* does not live at this depth and that these specimens were transported. This occurrence would also be explained if the water here had been much shallower during the Pleistocene, as seems likely.

Figure 3 shows the relations between temperature in degrees Fahrenheit, maximum size of specimens studied, and latitude. These data are not refined and more careful study may reveal some minor errors in the compilation. The one specimen *E. "crispum"* is that figured in Cushman and Grant

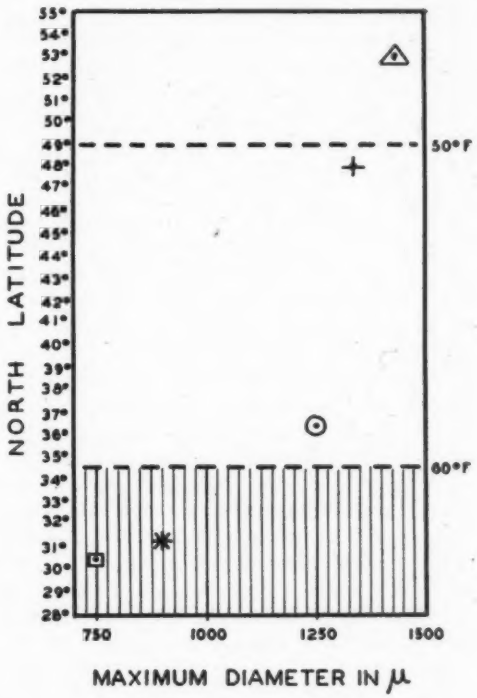


FIG. 3—Correlation between size, temperature, and latitude in West Coast Recent *Elphidium*. Temperature data based on average yearly temperature recorded by U. S. Hydrographic Office from 1915 to 1924.

(1922, pl, 7, figs. 3a, b). The maximum size was obtained from the measurement of 200 specimens unless otherwise indicated.

Several provisional conclusions may be drawn from a study of this figure. The most striking is that increase in size of specimens is related to decrease in temperature and increase in degrees north latitude. Probably temperature is the controlling factor. This is shown by the difference in size between the southern species (*Elphidium excubitor* and *E. concinnum*), which live in warm temperate or tropical waters, and *E. fax pingue* which lives in cool temperate seas. Changes in temperature thus appear to directly affect the geographic distribution of the species. This conclusion agrees with previous work, which has shown that in species, subspecies, and varieties of eastern Pacific marine invertebrates, size generally increases with a decrease in temperature.

The largest specimens observed are members of the Pleistocene subspecies, *E. fax barbarense*. The maximum size of greater diameter in 200 specimens is 1748 microns. This may indicate that the water temperature at Santa Barbara during early Pleistocene time was a few degrees lower than it is today along the Queen Charlotte Islands. The associated molluscan fauna is of a cold-water type.

COLLECTING LOCALITIES

1—Queen Charlotte Islands, British Columbia. *Elphidium*, n. sp. Specimens examined, 10; also Cushman and Grant's specimen (1927, pl. 7, figs. 3a, b).

2—Dallas Bank, Straits of Juan de Fuca, Washington. *E. fax fax*. Specimens examined, 200.

3—Moss Beach, San Mateo County, California. *E. fax pingue*. Specimens examined, 10.

4—Mussel Point, Monterey Bay, California. *E. fax pingue*. Specimens examined, 200.

5—Santa Barbara formation (lower Pleistocene), Santa Barbara, California. *E. fax barbarense*. Specimens examined, 200; Bagg's specimens (1912) probably came from here.

6—Natland's locality 118 (1933, table), San Pedro Channel off Santa Catalina Island, California (Pleistocene?). *Elphidium*, n. sp. Specimens examined, 143.

7—Lomita quarry, Los Angeles County, California (Pliocene or Pleistocene). *Elphidium*, n. sp. Specimens examined, 8.

8—Los Coronados Islands, N. Lat. 32°20′, off Coast of Lower California, Mexico. *E. excubitor*. Specimens examined, 7.

9—Ensenada, N. Lat. 31°51′, Lower California, Mexico. *E. concinnum*. Specimens examined, 5.

10—San Quintin, N. Lat. 30°25′, Lower California, Mexico. *E. concinnum*. Specimens examined, 7.

11—Punta Peñasco, N. Lat. 31° 20′, Gulf of California, Sonora, Mexico. *E. concinnum*, *E. excubitor*. Specimens examined, 200.

12—Adriatic Sea, Rimini, Italy. *E. macellum*. Specimens examined, 12.

DESCRIPTION OF SPECIES AND SUBSPECIES

Order FORAMINIFERA

Family NONIONIDAE Reuss, 1860

Subfamily ELPHIDIINAE Galloway, 1933

Genus ELPHIDIUM Montfort, 1808

Elphidium Montfort, Conch. Syst., vol. 1, 1808, p. 14.—Meek and Hayden, Smithsonian Contrib. to Knowledge, vol. 14, art. 5, 1865, p. 13, first revised synonomy of the genus and adopted *Elphidium*.—Cushman, Contrib. Cushman Lab. Foram. Res., vol. 3, pt. 1, 1927, p. 49.

Polystomella Lamarck, Hist. Anim. s. Vert., vol. 7, 1822, p. 625. Genotype, designated by Cushman, 1914, *Nautilus crispus* Linné.—Brady, Rep. Voy. Challenger, U. S. Nat. Mus. Bull. 71, pt. 4, 1914, p. 30.—Many authors.

Geophonus Montfort, *Pelorus* Montfort, *Andromedes* Montfort, *Sporilus* Montfort, *Themeon* Montfort, *Cellanthus* Montfort, *Vorticialis* Lamarck, *Polystomatium* Ehrenberg.—For more complete synonomy see Galloway (1933, p. 269) or Cushman (1939, p. 38).

Genoholotype, *Elphidium macellum* (Fichtel and Moll) = *Nautilus macellus* var. Fichtel and Moll, Text. Micr., 1798, p. 68, pl. 10, figs. h, i, k (Recent Mediterranean).

ELPHIDIUM FAX Nicol, n. sp.

This species can be divided into at least three subspecies, or geographic and geologic races: *Elphidium fax fax*, *E. fax pingue*, and *E. fax barbarense* distinguished mainly on size and number of chambers on the outer whorl. *Elphidium fax fax* and *E. fax pingue* occur in the Recent, intertidal zone, of the Pacific Coast of North America. Together they range from just north of Point Concepcion, California north at least to the Straits of Juan de Fuca, Washington. *E. fax barbarense* occurs in the Santa Barbara formation, lower Pleistocene, at Santa Barbara, California. For further details concerning geographic and geologic distribution of this species refer to the map, text figure 2.

ELPHIDIUM FAX FAX Nicol, n. subsp.
Plate 29, figures 3, 11

Description.—Test lenticular, planispirally coiled, involute, normally bilaterally symmetrical, periphery sometimes irregular, never lobulate, wall hyaline, finely perforate; chambers slender, gently curved, from 10 to 25 in outer whorl, mean 19.5, last chambers wider in largest specimens; keel surrounding periphery, of clear shell material, narrow, angular; septa limbate, gently curved, of clear shell material, retral processes 13 to 16 on last chambers, connecting one septum with another except in last 3 to 7 chambers in large specimens where they fail to reach front septum, on some chambers scarcely visible; umbilical plug large, of clear shell material, with few large pores on surface, umbonate; aperture of 6 to 12 large pores at base of apertural face along periphery, occasional smaller pores below center of apertural face, remainder of apertural face smooth.

Dimensions of 200 specimens:	Min.	Max.	Mean
Greater diameter	430μ	1340μ	1031μ
Thickness	190μ	532μ	406μ

Comparisons.—The nearest relatives of *Elphidium fax fax* are *E. fax pingue* and *E. fax barbarense*. For comparisons of size refer to correlation tables; for comparisons of ratio of dimensions refer to appendix 3.

Elphidium fax fax is as much as 500μ larger than topotypes of *E. macellum*. It also averages 4 more chambers in the outer whorl, has a larger umbilical plug and less curved septa.

Occurrence.—The type locality of this subspecies is L.S.J.U. loc. 2673, Dallas Bank, Straits of Juan de Fuca, Clallam County, Washington, North Latitude 48°. Its precise geographic extent north and south of this locality is not now known.

ELPHIDIUM FAX PINGUE Nicol, n. subsp.
Plate 29, figures 1, 2

Elphidium crispum Schenck, 1940, Am. Assoc. Petroleum Geologists Bull., vol. 24, no. 10, p. 1761, fig. 4.

Description. .—Resembles *E. fax fax* except for smaller number of chambers in outer whorl, 11 to 23, mean 18.2, P of differences in maximum chamber number 0.002; in being proportionately thicker, ratio of thickness to greater diameter 0.488 as compared with 0.394 in *E. fax fax*, P in this difference 0.09; in being smaller, 1254μ as compared with 1340μ for maximum in sample of 200 which is significant, P being 0.0001.

Dimensions of 200 specimens:	Min.	Max.	Mean
Greater diameter	470μ	1254μ	899μ
Thickness	248μ	618μ	434μ

Comparisons.—The nearest relatives of *Elphidium fax pingue* are *E. fax fax* and *E. fax barbarense*. For comparisons of size consult the correlation tables; for comparison of ratio of dimensions refer to appendix 3. *E. fax pingue* is 300μ larger than the southern species *E. excubitor* and *E. concinnum*.

E. fax pingue is proportionately thicker and 400μ larger than *E. macellum*. It also differs in having more chambers in the outer whorl, a larger umbilical plug, and less curved septa than the Mediterranean species.

Occurrence.—The type locality of this subspecies is L.S.J.U. loc. 1164, Mussel Point, Monterey Bay, Monterey County, California, North Latitude 36° 37′. *Elphidium fax pingue* extends as far south as San Luis Bay, San Luis Obispo County, California and at least as far north as Moss Beach, San Mateo County, California.

ELPHIDIUM FAX BARBARENSE
Nicol, n. subsp.
Plate 29, figures 10, 12

Polystomella crispa (Linné), Bagg, 1912, U. S. Geol. Survey Bull. 513, pp. 90, 91, pl. 27, figs. 13–20; pl. 28, figs. 1–6.

Description.—Larger than *E. fax fax*, maximum size in sample of 200 1748μ as compared to 1340μ which is significant, P being 0.0001; except: has larger number of chambers in outer whorl, 13 to 28, mean 20.5, P of differences in maximum chamber number 0.0001; retral processes stained buff to reddish brown, 15 to 17 on last chambers, aborted in only last 2 or 3 chambers, this gerontic tendency not as marked as in *E. fax fax* or *E. fax pingue.*

Dimensions of 200 specimens:	Min.	Max.	Mean
Greater diameter	650μ	1748μ	1178μ
Thickness	295μ	695μ	489μ

Comparisons.—The most closely allied species to *E. fax barbarense* are *E. fax fax* and *E. fax pingue.* For differences in size refer to correlation tables; for differences in ratio of dimensions refer to appendix 3.

E. fax barbarense, the largest form studied, should not be confused with *E. macellum* and *E. excubitor* which are only half as big.

Occurrence.—The type locality of this subspecies is L.S.J.U. loc. 2407, Santa Barbara formation (lower Pleistocene), Santa Barbara, Santa Barbara County, California, North Latitude 34° 24′. Some specimens from Natland's locality #118 (1933, table) off Santa Catalina Island appear to be a subspecies closely resembling *E. fax barbarense.*

Galloway and Wissler (1927, pp. 82, 83) described *Themeon crispus* from Pleistocene beds at Lomita quarry, Palos Verdes Hills, California. This locality is about 20 miles south of Los Angeles. The specimen figured is less than half the size and is proportionately thicker than *E. fax barbarense.* It appears to be about the same size as a similar species, *E. excubitor*, living off the coast south of San Diego today. The size of "*Themeon crispus*" agrees with temperature data presented by Grant (1936, pp. 349–350) for the Lomita formation. He surmised that the probable mean surface water temperature was 62°F. which is approximately the mean temperature found off the coast of Southern California south of Point Concepcion today.

Closer study will no doubt reveal several Pleistocene species and subspecies which are allied to Recent species. Whether any living related species ranges from the Pliocene is an unanswered question.

ELPHIDIUM EXCUBITOR Nicol, n. sp.
Plate 29, figures 4, 8

Description.—Test lenticular, planispirally coiled, involute, normally bilaterally symmetrical, periphery sometimes irregular, never lobulate, wall hyaline, finely perforate; chambers slender, gently curved, 10 to 19 in outer whorl, mean 15.5, the last chambers wider in few larger specimens; keel surrounding periphery, of clear shell material, narrow or angular; septa of clear shell material, gently curved, limbate; retral processes 9 to 11 on last chambers, connecting one septum with another except in last 2 or 3 chambers of some large specimens where they fail to reach front septum; umbilical plug small, of clear shell material, having a few large pores on surface, umbonate; aperture of 6 to 12 large pores at base of apertural face along periphery, occasionally smaller pores below center of apertural face, remainder of apertural face smooth.

Dimensions of 200 specimens:	Min.	Max.	Mean
Greater diameter	385μ	850μ	611μ
Thickness	195μ	418μ	292μ

Comparisons.—This species resembles *E. macellum* in size but differs in being proportionately thicker, having less curved septa, and a larger and more distinct umbilical plug.

It differs from *E. concinnum* in having fewer chambers in the outer whorl, a more angular keel, and by its gerontic tendency for the retral processes to be aborted in the last chambers of the outer whorl.

The differences between it and the subspecies of *E. fax*, are indicated in the correlation tables.

Occurrence.—The type locality of this species is L.S.J.U. loc. 2650, Punta Peñasco, Sonora, Mexico, North Latitude 31° 21′. *E. excubitor* occurs also at Los Coronados Islands.

ELPHIDIUM CONCINNUM Nicol, n. sp.
Plate 29, figures 5, 9

Elphidium crispum (Linné), Cushman and Grant, 1927, San Diego Soc. Natural History Trans., vol. 5, no. 6, figs. 2a, b.
Elphidium crispum (Linné), Cushman and Valentine, 1930, Dept. Geol. Stanford Univ. Contr., vol. 1, no. 1, p. 21, pl. 5, figs. 12a, b.

Description.—Test lenticular, planispirally coiled, involute, bilaterally symmetrical, periphery regular, wall whitely translucent, finely perforate; chambers slender, gently curved, 14 to 23 in outer whorl; keel surrounding periphery, of clear shell material, small, rounded; septa limbate, gently curved, of clear shell material; retral processes 9 to 12 on last chambers, connecting one septum with another, never aborted; umbilical plug small, of clear shell material, having a few pores on surface, not umbonate; aperture 6 to 12 large pores at base of apertural face along periphery, occasional smaller pores below center of small apertural face.

Dimensions of holotype:

Greater diameter	646μ
Thickness	286μ

Comparisons.—Morphologically *Elphidium concinnum* is the most distinct species studied. It has about the same size range as *E. excubitor* and *E. macellum*, but it differs from both in having a more gently rounded periphery, more chambers in the outer whorl (narrower chambers), and never showing the gerontic abortion of the retral processes on the last chambers. Other differences, such as the whitely translucent test and the nonumbonate umbilical plug, aid in separating this species from its allies. *E. concinnum* is also more obese and has more gently curved septa than does *E. macellum*.

E. concinnum is from two-thirds to one-half the size of *E. fax*.

Occurrence.—The type locality is L.S.J.U. loc. 1543, San Quentin, Lower California, Mexico, North Latitude 30° 25′. *E. concinnum* occurs in samples with *E. excubitor* at many places off the coast of Lower California. It is abundant at Ensenada, and rare in material from the intertidal zone at Punta Peñasco in the Gulf of California. Its exact ecologic relationship to *E. excubitor* is not known. The worn condition of specimens collected in the intertidal zone at Punta Peñasco may indicate that *E. concinnum* is a deeper water species.

APPENDIX 1. EFFECT ON MAXIMUM SIZE BY ADMIXTURE OF ANOTHER LARGER SPECIES

The maximum size calculated by adding three times the standard deviation to the mean ($3Sx+\bar{x}$), includes over 99 percent of the cases if the distribution is normal. The following results were obtained by this method:

	Greater Diameter		Lesser Diameter	
	Observed (Microns)	Calculated (Microns)	Observed (Microns)	Calculated (Microns)
U.	905	852	808	761
M.	1254	1492	1150	1305
D.	1340	1545	1264	1412
S.	1748	1976	1530	1792
	Thickness (microns)	(microns)	Chambers in Outer Whorl	
U.	418	426	23	20.5
M.	618	662	23	24.8
D.	532	604	25	27.2
S.	695	770	28	31.1

As the figures show, the calculated maximum is larger than the observed maximum except in three cases and in another case it is nearly the same. These cases all occur in the sample taken from Punta Peñasco, Mexico. It was later discovered that a second species occurring very rarely in this sample attains a slightly larger maximum size and has more chambers in the outer whorl (the chambers were narrower) than the more common intertidal species, *Elphidium excubitor*. This second species has been described as *E. concinnum*.

APPENDIX 2. SIGNIFICANCE OF MAXIMUM SIZE AND CHAMBER COUNT DIFFERENCES

Maximum size was used rather than mean size because the smallest specimens were not available. Small shells of young individuals, are more fragile and easily destroyed by waves and predatory animals. Without the smaller sizes the location of the mean would naturally be affected. The maximum size, therefore, was the only stable measure that could be used in comparing species, or communities within a species.

The maximum expected size was set at $3Sx+\bar{x}$ for symmetrical distribution. The significance of the differences between maxi-

mum sizes was tested by the following formula:

$$k = \frac{Max_1 - Max_2}{\sqrt{SE^2_{Max_1} + SE^2_{Max_2}}}.$$

For the square of the standard error (variance) of the maximum, the sum of the variances of the mean and the standard deviation were used since both entered into the estimate of the maximum size.

The probability corresponding to the values of k, the relative deviate, was obtained from the usual tables.

All values for all probable comparisons of the measurements are shown below. It will be seen that in every case but one the probability of obtaining a difference as great as that found through random sampling alone is less that 1 in 10,000, and that therefore the differences between maximum sizes for the samples are significant.

GREATER DIAMETER IN MICRONS

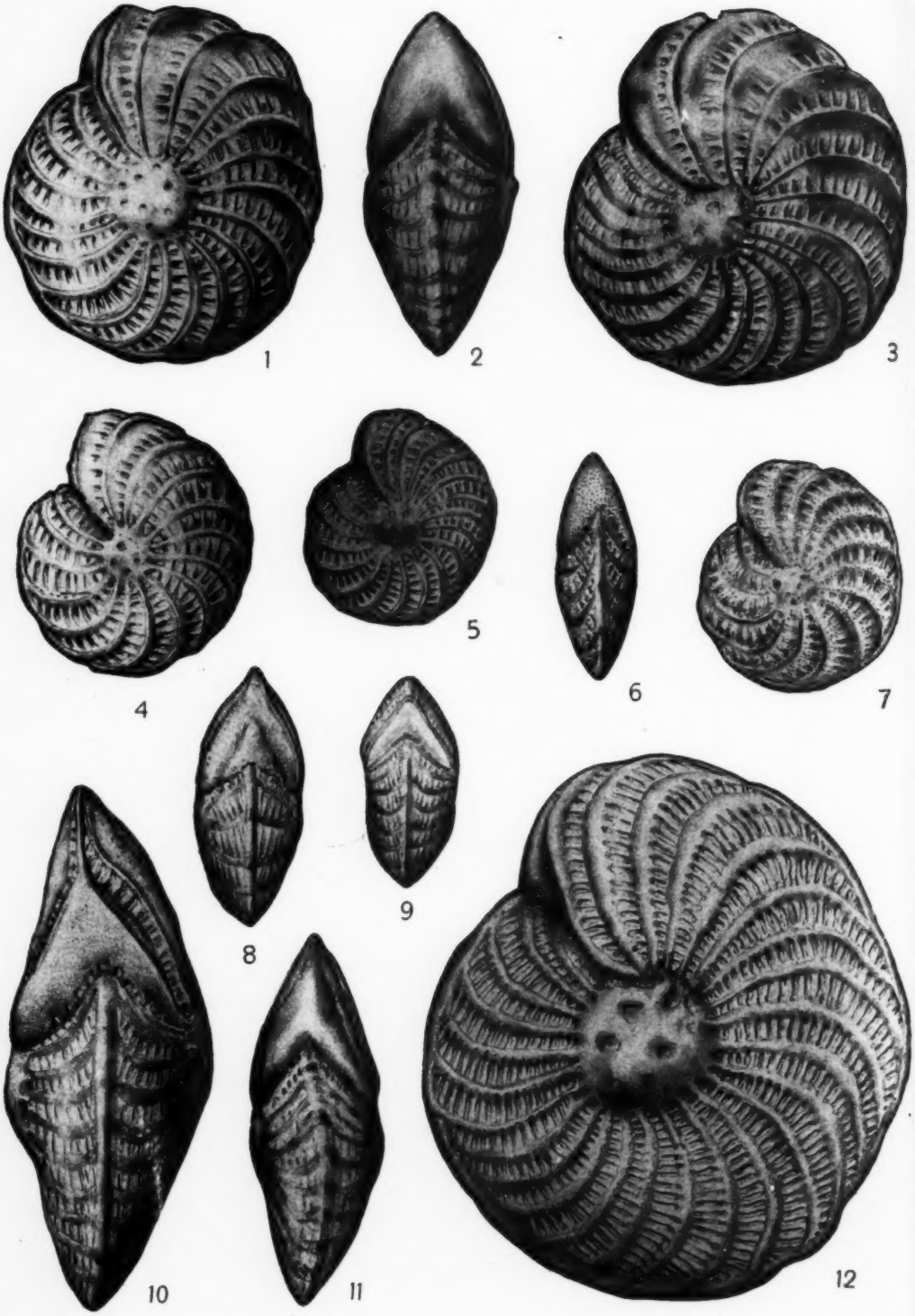
	S.		D.		M.	
U.	Max	1075.92	Max	654.41	Max	529.32
	SE	24.06	*SE*	16.39	*SE*	16.81
	k	44.7	*k*	40.0	*k*	31.5
	P	0.0001	*P*	0.0001	*P*	0.0001
M.	Max	546.59	Max	116.09		
	SE	27.65	*SE*	21.32		
	k	20.0	*k*	5.5		
	P	0.0001	*P*	0.0001		
D.	Max	430.51				
	SE	27.40				
	k	15.7				
	P	0.0001				

LESSER DIAMETER IN MICRONS

	S.		D.		M.	
U.	Max	992.43	Max	612.70	Max	505.32
	SE	22.46	*SE*	15.83	*SE*	15.89
	k	44.1	*k*	39.0	*k*	32.0
	P	0.0001	*P*	0.0001	*P*	0.0001
M.	Max	487.11	Max	107.38		
	SE	25.96	*SE*	20.49		
	k	18.9	*k*	5.2		
	P	0.0001	*P*	0.0001		
D.	Max	379.73				
	SE	25.92				
	k	14.9				
	P	0.0001				

THICKNESS IN MICRONS

	S.		D.		M.	
U.	Max	343.97	Max	177.38	Max	235.05
	SE	9.03	*SE*	6.92	*SE*	7.67
	k	38.0	*k*	25.0	*k*	30.0
	P	0.0001	*P*	0.0001	*P*	0.0001
M.	Max	108.92	Max	−57.67		
	SE	10.48	*SE*	8.73		
	k	10.4	*k*	6.6		
	P	0.0001	*P*	0.0001		
D.	Max	166.59				
	SE	9.95				
	k	16.7				
	P	0.0001				



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CHAMBER NUMBER ON OUTER WHORL

	S.		D.		M.	
U.	Max	10.62	Max	6.69	Max	4.30
	SE	0.82	*SE*	0.60	*SE*	0.52
	k	13.0	*k*	11.0	*k*	8.0
	P	0.0001	*P*	0.0001	*P*	0.0001
M.	Max	6.32	Max	2.39		
	SE	0.96	*SE*	0.77		
	k	6.4	*k*	3.1		
	P	0.0001	*P*	0.0019		
D.	Max	3.93				
	SE	1.0				
	k	3.9				
	P	0.0001				

APPENDIX 3. SIGNIFICANCE OF COMPARISONS BETWEEN VARIOUS DIMENSION RATIOS

Four ratios of the means of dimensions were used corresponding to those in the correlation tables as follows:

	L.D./G.D.	Th./G.D.	Ch.n./G.D.	Ch.n./Th.
U.	0.882	0.478	0.026	0.055
M.	0.892	0.482	0.020	0.042
D.	0.884	0.394	0.019	0.048
S.	0.889	0.415	0.017	0.042

The figures in the first column indicate that in these closely related species the width of the outer whorl bears a nearly constant relation to the total size.

The figures in the second column show that specimens from the Straits of Juan de Fuca, Washington are the thinnest and that the Pleistocene specimens are next thinnest. The greatest differences in ratios exist between the sample from Washington (*Elphidium fax fax*) and the sample from Monterey Bay, California (*Elphidium fax pingue*). These differences are interesting but not very significant as following data show.

The figures in the third column indicate that when the samples are arranged in the order of increasing size, which is also the approximate order of decreasing temperature, the number of chambers of the outer whorl decreases in relation to the size.

The figures in the last column have no significance and fail to show a trend.

The following formulas were taken from Pearl (1940, p. 370) and applied to find if any of the comparisons of ratios were significantly different. Symbols were altered only to correspond with those used in this paper

EXPLANATION OF PLATE 29

All specimens illustrated are in Stanford University Paleontological Type Collection. All figures ×45.

FIGS. *1, 2—Elphidium fax pingue* Nicol, n. subsp. Recent, Mussel Point, Monterey Bay, Monterey Co., California; *1*, Side view, *2*, Apertural view, holotype 5461. (p. 177)

3, 11—Elphidium fax fax Nicol, n. sub. sp. Recent, Dallas Bank, Straits of Juan de Fuca, Clallam Co., Washington; *3*, Side view. *11*, Apertural view, holotype 5462. (p. 177)

4, 8—Elphidium excubitor Nicol, n. sp. Recent, Punta Peñasco, Sonora, Mexico; *4*, Side view of holotype. *8*, Apertural view, holotype 5463. (p. 178)

5, 9—Elphidium concinnum Nicol, n. sp. Recent, San Quintin, Lower California, Mexico; *5*, Side view. *9*, Apertural view, holotype. (p. 179)

6, 7—Elphidium macellum (Fichtel and Moll). Recent, Rimini, Italy; *6*, Apertural view. *7*, Side view, hypotype 5465.

10, 12—Elphidium fax barbarense Nicol, n. subsp. Pleistocene, Santa Barbara Formation, Santa Barbara, Santa Barbara County, California; *10*, Apertural view. *12*, Side view, holotype 5466. (p. 178)

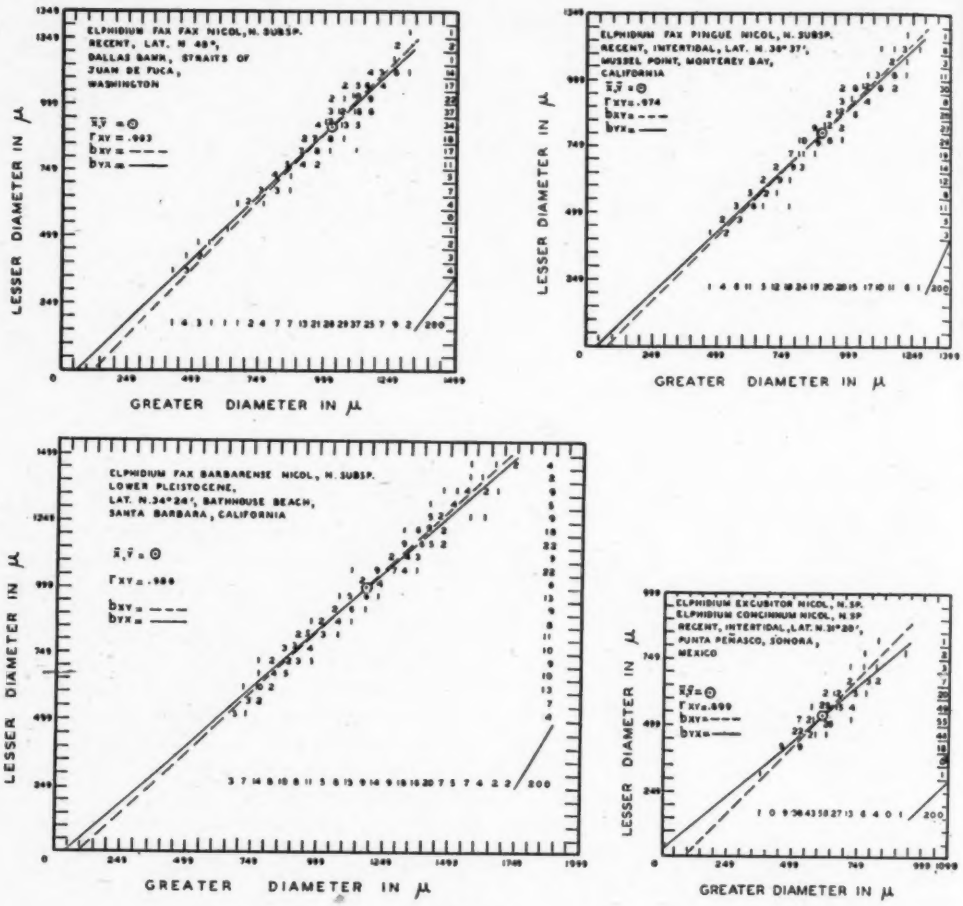
ELPHIDIUM FAX FAX NICOL, N. SUBSP.
RECENT, LAT. N 48°,
DALLAS BANK, STRAITS OF
JUAN DE FUCA,
WASHINGTON
LESSER DIAMETER IN μ
GREATER DIAMETER IN μ
ELPHIDIUM FAX PINGUE NICOL, N. SUBSP.
RECENT, INTERTIDAL, LAT. N. 36° 37',
MUSSEL POINT, MONTEREY BAY,
CALIFORNIA
ELPHIDIUM FAX BARBARENSE NICOL, N. SUBSP.
LOWER PLEISTOCENE,
LAT. N. 34° 24', BATHHOUSE BEACH,
SANTA BARBARA, CALIFORNIA
ELPHIDIUM EXCUBITOR NICOL, N. SP.
ELPHIDIUM CONCINNUM NICOL, N. SP.
RECENT, INTERTIDAL, LAT. N. 31° 20',
PUNTA PEMASCO, SONORA,
MEXICO

FIG. 4

Value of Ratio

$$R=\frac{\bar{x}_1}{\bar{x}_2}\left[1+\left(\frac{Sx_2}{\bar{x}_2}\right)-\gamma_{1.2}\frac{Sx_1}{\bar{x}_1}\frac{Sx_2}{\bar{x}_2}\right].$$

Standard Deviation of Ratio

$$SR=\frac{\bar{x}_1}{\bar{x}_2}\sqrt{\left(\frac{Sx_1}{\bar{x}_1}\right)^2+\left(\frac{Sx_2}{\bar{x}_2}\right)^2-2\gamma_{1.2}\frac{Sx_1}{\bar{x}_1}\frac{Sx_2}{\bar{x}_2}}$$

Relative Deviate

$$k=\frac{R_1-R_2}{\sqrt{SR_1^2+SR_2^2}}.$$

Most of the ratios were not significantly different, indicating a similarity of form in the species and subspecies studied. The three most significant comparisons are as follows:

1. $\frac{\text{Ch.n.}}{\text{G.D.}}$

(U.) $R_1=0.02638$ (U.) $SR_1^2=0.000009$ $k=2.630$
(S.) $R_2=0.01765$ (S.) $SR_2^2=0.000002$ $P=0.0085$

2. $\frac{\text{Ch.n.}}{\text{G.D.}}$

(U.) $R_1=0.02638$ (U.) $SR_1^2=0.000009$ $k=2.207$
(D.) $R_2=0.01905$ (D.) $SR_2^2=0.0000021$ $P=0.0273$

3. $\frac{\text{Th.}}{\text{G.D.}}$

(M.) $R_1=0.48576$ (M.) $SR_1^2=0.00163$ $k=1.687$
(D.) $R_2=0.39679$ (D.) $SR_2^2=0.00115$ $P=0.0924$

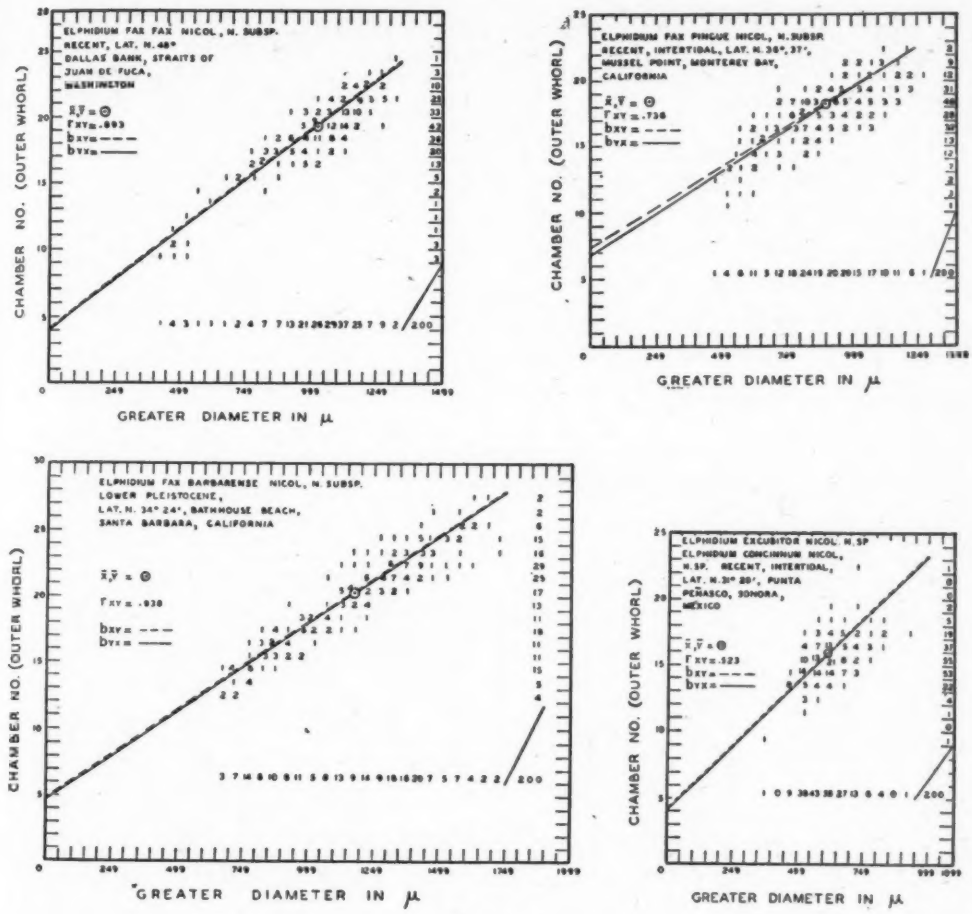

FIG. 5

Correlation tables showing sizes of various dimensions, the mean, the coefficient of correlation, and the regression coefficients of the species and subspecies of *Elphidium* (figs. 4–7).

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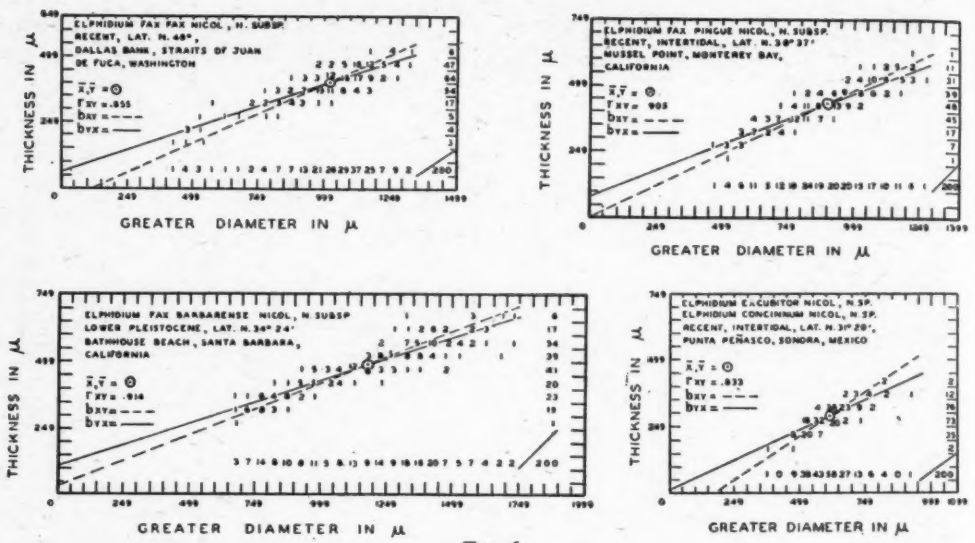
ELPHIDIUM FAX FAX NICOL, N. SUBSP.
RECENT, LAT. N. 48°,
DALLAS BANK, STRAITS OF JUAN DE FUCA, WASHINGTON
ELPHIDIUM FAX PINGUE NICOL, N. SUBSP.
RECENT, INTERTIDAL, LAT. N. 36° 37'
MUSSEL POINT, MONTEREY BAY, CALIFORNIA
ELPHIDIUM FAX BARBARENSE NICOL, N SUBSP
LOWER PLEISTOCENE, LAT. N. 34° 24'
BATHHOUSE BEACH, SANTA BARBARA, CALIFORNIA
ELPHIDIUM EXCUBITOR NICOL, N SP.
ELPHIDIUM CONCINNUM NICOL, N SP.
RECENT, INTERTIDAL, LAT. N. 31° 20',
PUNTA PEÑASCO, SONORA, MEXICO
THICKNESS IN μ
GREATER DIAMETER IN μ

FIG. 6

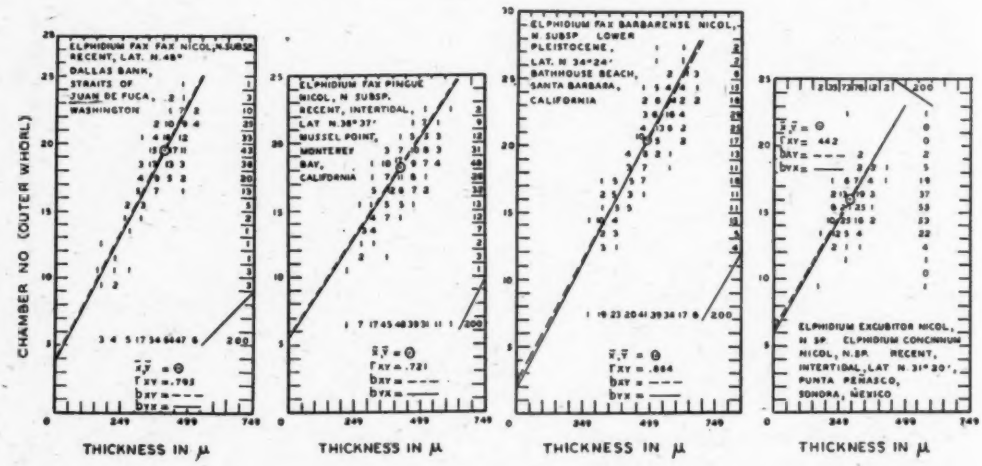
ELPHIDIUM FAX FAX NICOL, N.SUBSP.
RECENT, LAT. N. 48°
DALLAS BANK, STRAITS OF JUAN DE FUCA, WASHINGTON
ELPHIDIUM FAX PINGUE NICOL, N SUBSP.
RECENT, INTERTIDAL, LAT. N. 36° 37'
MUSSEL POINT, MONTEREY BAY, CALIFORNIA
ELPHIDIUM FAX BARBARENSE NICOL, N SUBSP LOWER PLEISTOCENE, LAT. N. 34° 24'
BATHHOUSE BEACH, SANTA BARBARA, CALIFORNIA
ELPHIDIUM EXCUBITOR NICOL, N SP. ELPHIDIUM CONCINNUM NICOL, N SP. RECENT, INTERTIDAL, LAT. N. 31° 20', PUNTA PEÑASCO, SONORA, MEXICO
CHAMBER NO. (OUTER WHORL)
THICKNESS IN μ

FIG. 7

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JOURNAL OF PALEONTOLOGY, VOL. 18, NO. 2, PP. 186–203, PLS. 30–34, 5 TEXT FIGS., MARCH 1944

FORAMINIFERA FROM THE TUMEY FORMATION, FRESNO COUNTY, CALIFORNIA[1]

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AND
RUSSELL R. SIMONSON
Pomona, California

ABSTRACT—This paper records the foraminiferal fauna of the Tumey formation from which few forms have been described previously. Specimens were obtained from outcrops and a well drilled near the type locality. Three zones are recognized in the formation, which is considered to be Oligocene or Upper Eocene in age.

INTRODUCTION

THE Tumey formation outcropping along the western border of the San Joaquin Valley has been found to contain abundant but poorly preserved Foraminifera. To date very few forms have been described from this formation because of the difficulty of obtaining suitable material from the exposed sections; however, wells drilled a few miles east of the surface outcrops have yielded cores containing well-preserved Foraminifera throughout the Tumey interval.

This paper records Foraminifera of the Tumey formation as found in outcrop and in equivalent beds in the Seaboard Oil Co.'s Welch No. 1 well. This well is located 1708 feet south and 2036 feet west of the NE cor. sec. 10, T.16 S., R.13 E., M.D.M., approximately 1¼ miles from the type locality of the Tumey formation as designated by E. R. Atwill (1935, p. 1204), i.e., "in the S.½ sec. 16, T.16 S., R.13 E., Mount Diablo Base and Meridian, Fresno County, California." Permission to describe and figure Foraminifera from this well has been granted through the courtesy of L. S. Chambers, W. D. Kleinpell, N. A. Rousselot, and C. P. Watson of the Seaboard Oil Company and E. B. Nobel of the Union Oil Company.

The writers wish to acknowledge the helpful criticisms and suggestions of E. R. Atwill, W. F. Barbat, Glenn C. Ferguson, R. B. Hutcheson, Olaf P. Jenkins, R. M. Kleinpell, W. D. Kleinpell, Max L. Krueger, H. G. Schenck, S. S. Siegfus, Norman L. Thomas, and Frank B. Tolman.

No attempt is made to review the literature on the age and divisions of the Tumey formation in the Ciervo Hills district (the area between Tumey Gulch and Cantua Creek). The accompanying chart (fig. 1) outlines various conceptions of the stratigraphy in the vicinity of the type locality. The papers listed in the bibliography should be consulted for detailed descriptions. Jenkins' (1931) paper contains an excellent summary of ideas on the divisions of Eocene and Oligocene sediments of this region.

TUMEY FORMATION[2]

The Tumey formation, or its equivalent, outcrops intermittently along the western

[1] Published by permission of the Acting Director, Geological Survey, Department of the Interior.

[2] According to current usage among California geologists, the term Tumey formation is applied to a cartographic unit 1600 feet thick that outcrops in the Cantua-Panoche Creeks district and consists of sandstone overlain by shale; the term Kreyenhagen shale is restricted to the shale that underlies the sandstone. Away from the outcrop area the basal sandstone member of the Tumey grades laterally into shale that is not lithologically separable from the underlying Kreyenhagen shale. In the subsurface section described in this report (Seaboard Oil Company's "Welch" No. 1 well, 1¼ miles northeast of the outcrop area), the fauna of the beds that are correlated with the sandstone member of the outcrop area is described as a mixture of the faunas of the underlying Kreyenhagen shale and of the *Uvigerina cocoaensis* zone, which is correlated with the shale member of the outcrop area. Because of the difficulty of separating the Tumey formation from the underlying shale at places where the basal sandstone member is not present, the Geological Survey has not considered the adoption of the term Tumey formation and classifies these beds as the upper part of the Kreyenhagen shale.

COMPARISON OF STRATIGRAPHIC SECTIONS OF VARIOUS AUTHORS IN THE VICINITY OF THE TYPE LOCALITY OF THE TUMEY FORMATION FOR MIOCENE, OLIGOCENE AND UPPER EOCENE STRATA OF THE CIERVO HILLS DISTRICT

Pack and Anderson (1915)		D. D. Condit (1930)	Olaf P. Jenkins (1931)	E. R. Atwill (1935)	This Paper	This Paper	
U.S.G.S. Bulletin No. 603.		Jour. Paleontology Vol. 4, No. 3, pp. 259–262	Mining in California Vol. 27, No. 2, pp. 141–186	A.A.P.G. Bulletin Vol. 19, No. 8, p. 1197	TYPE SECTION	WELL SECTION	
General Section	Arroyo Ciervo District	Generalized section near Arroyo Ciervo.	Section north of Arroyo Ciervo.	Section near NW side of Arroyo Ciervo.	S. ½ sec. 16, 16S–13E M.D.M.	Seaboard Welch No. 1, sec. 10, 16S–13E M.D.M.	
"VAQUEROS" SANDSTONE		TEMBLOR SANDSTONE	TEMBLOR SANDSTONE	TEMBLOR SANDSTONE	TEMBLOR SANDSTONE	TEMBLOR SANDSTONE	MIOCENE
Unconformity		Unconformity	Unconformity	Unconformity	Unconformity	Unconformity	
OLIGOCENE (?) KREYENHAGEN FORMATION	KREYENHAGEN	KREYENHAGEN SHALE: "A" horizon ("maximum thickness 5 to 10 feet") ("Not sharply divisible from horizon "A")	*LEDA* ZONE	"*LEDA*" ZONE	MISSING BY UNCONFORMITY	"*LEDA*" ZONE	OLIGOCENE
			Unconformity	Questionable Unconformity	TUMEY FORMATION: SHALE MEMBER	Unconformity	
		"B" horizon ("Several hundred feet thick")	"SHALE AND SANDSTONE MEMBER OVERLYING THE KREYENHAGEN SHALE"	TUMEY SHALE		*UVIGERINA COCOAENSIS* ZONE	
	"FAULTED VAQUEROS" SANDSTONE	"C" horizon ("400 feet or more in maximum development")		TUMEY SANDSTONE	SANDSTONE MEMBER	TRANSITION ZONE (Sandstone member wedges out or grades to shale) Shell fragments	TUMEY FORMATION
		"Buckshot sand"	Contact intrusive in part.	Fossil reef	Fossil reef		
	KREYENHAGEN	Unconformity	Unconformity	Unconformity	Unconformity?	KREYENHAGEN SHALE Total Depth.	EOCENE
		"D" horizon ("1,000 feet or more in thickness")	KREYENHAGEN SHALE	KREYENHAGEN SHALE	KREYENHAGEN SHALE		

FIG. 1

border of the San Joaquin Valley from Devils Den to Tumey Gulch and is known to underlie a large portion of the middle and southern San Joaquin Valley. Thickness and lithologic character of this formation are subject to variation because of unconformities and lateral gradation.

In outcrop the Tumey formation, consisting of an upper shale member and a lower sandstone member, comprises a cartographic unit between Tumey Gulch and Arroyo Ciervo. A complete section of the Tumey formation is present only in the vicinity of Arroyo Ciervo. Northwesterly from Arroyo Ciervo the overlying Miocene Temblor sandstone progressively overlaps the shale and sandstone of the Tumey formation; north of Tumey Gulch the entire Tumey formation is missing from the surface section. South of Arroyo Ciervo the upper portion of the shale member is overlapped by Temblor sandstone, and the sandstone member of the Tumey has either graded to shale or wedged out, permitting the lower part of the Tumey shale to rest upon the restricted Kreyenhagen shale with

no intervening sandstone. A study of the areal map (fig. 2) will further clarify these relationships.

On a paleontologic basis the writers have divided the Tumey formation in the Ciervo Hills district into three parts; the "*Leda*" zone, the *Uvigerina cocoaensis* zone and the transition zone.

"LEDA" ZONE

The "*Leda*" zone in the upper part of the shale member of the Tumey formation is present in outcrop for only a short distance north and south of Arroyo Ciervo. In the Seaboard Oil Co.'s Welch No. 1 well the "*Leda*" zone was continuously cored from 3298 to 3462 feet. It includes 141 feet (stratigraphic thickness) of steel-gray to brown ashy shales that carry distinctive mollusks and Foraminifera. Glauconite and sporbo are common in the upper 5 feet of the "*Leda*" zone, and there is also a thin glauconite zone at the base. It is believed that there is good evidence for an unconformity at the top and the base of the "*Leda*" zone.

Abundant mollusks are found in the upper 20 feet of this zone and scattered megafossils are present throughout the remainder. The following diagnostic mollusks were found in the well section:

"*Leda*" (*Nuculana*) *washingtonensis* Weaver
Macrocallista pittsburgensis Dall
Acila (*Truncacila*) *shumardi* (Dall)

The foraminiferal faunule of the "*Leda*" zone is distinctive. Some of the characteristic forms are:

Cassidulina sp.
Nonion olssoni (W. Berry)
Nonionella sp.
Uvigerina gallowayi Cushman
Virgulina recta Cushman

An examination of the check list for the well section will indicate in detail the faunular differences between the "*Leda*" zone and the underlying *Uvigerina cocoaensis* zone. The microfauna of the "*Leda*" zone shows affinity to lower Miocene assemblages as well as to the *Uvigerina cocoaensis* zone.

UVIGERINA COCOAENSIS ZONE

In the Seaboard Oil Co.'s Welch No. 1 well the *Uvigerina cocoaensis* zone occurs between 3462 to 3830 feet and comprises 184 feet (stratigraphic thickness) of light and dark brown diatomaceous clay-shales. A few scattered thin streaks of gray sand

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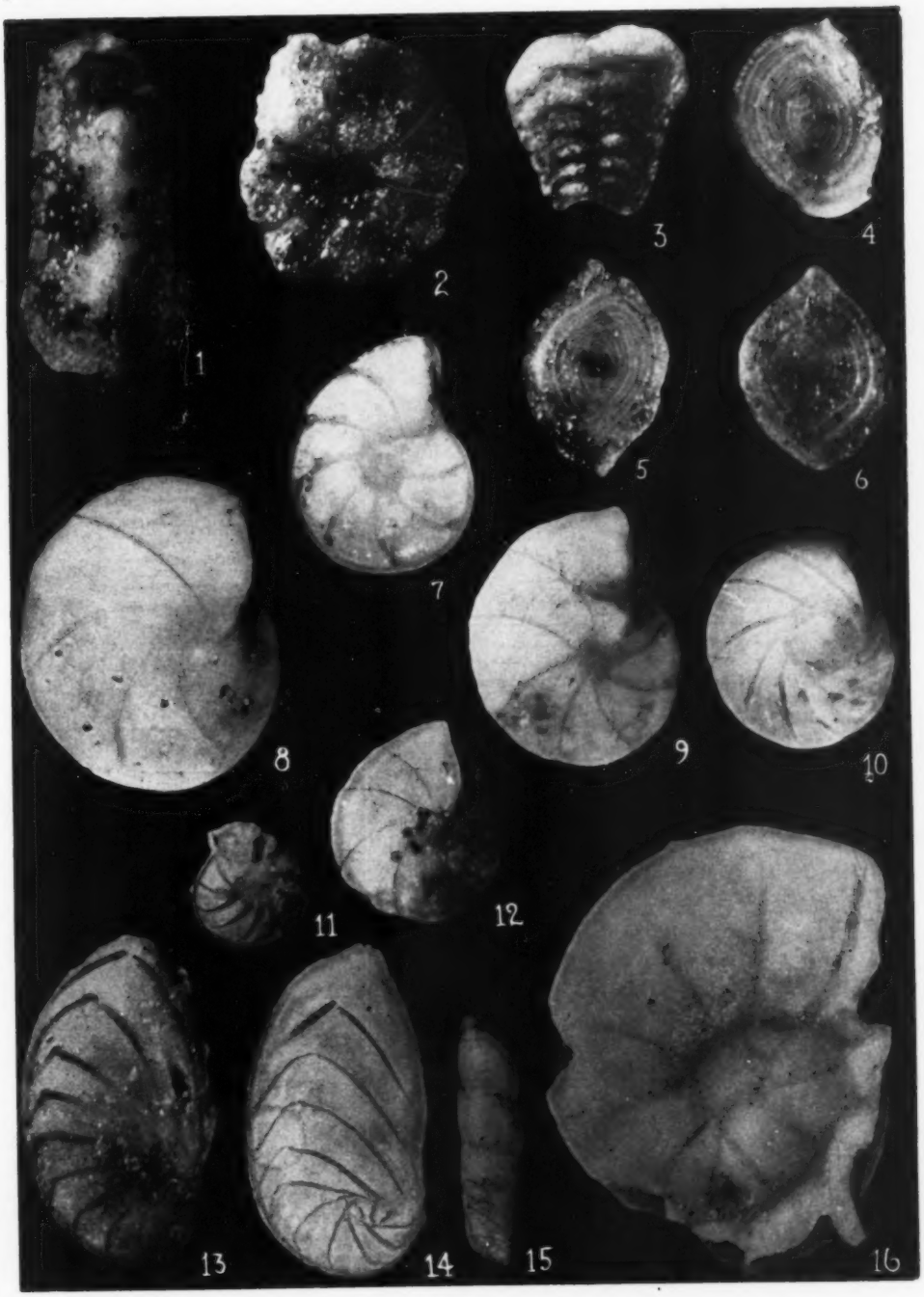
EXPLANATION OF PLATE 30

(All magnifications ×90, except fig. 8)

FIGS. *1*—*Bathysiphon eocenica* Cushman and G. D. Hanna. Tumey formation, at a depth of 3695 feet, in Seaboard Oil Co.'s Welch No. 1 well, Fresno Co., Calif. (p. 193)
2—*Cyclammina* cf. *C. samanica* W. Berry. Kreyenhagen formation, from 4215-foot sample. (p. 193)
3—*Textularia?* sp. Tumey formation, from 3970-foot sample. (p. 193)
4–6—*Spiroloculina wilcoxensis* Cushman and Garrett. Tumey formation, from 4050-foot sample. (p. 194)
7—*Robulus articulatus texanus* (Cushman and Applin). Tumey formation, from 3630-foot sample. (p. 194)
8—*Robulus* cf. *R. alato-limbatus* (Gümbel). Tumey formation, from 3615-foot sample. ×130. (p. 194)
9—*Robulus limbosus hockleyensis* (Cushman and Applin). Tumey formation, from 3740-foot sample. (p. 194)
10—*Robulus* cf. *R. arcuato-striatus carolinianus* Cushman. Tumey formation, from 3655-foot sample. (p. 194)
11—*Robulus welchi* Church. Tumey formation, from 4152–61-foot sample. (p. 195)
12—*Lenticulina* cf. *L. convergens* (Bornemann). Tumey formation, from 3818-foot sample. (p. 195)
13, *14*—*Planularia tolmani* Cushman and Simonson, n. sp. Tumey formation. *13*, Paratype, from 3635-foot sample. *14*, Holotype, from 3720-foot sample. (p. 195)
15—*Marginulina* sp. Tumey formation, from 3515-foot sample. (p. 196)
16—*Planularia* sp. Tumey formation, from 3550-foot sample. (p. 195)



Cushman and Simonson, Eocene and Oligocene Foraminifera

UNIV. OF MICH.

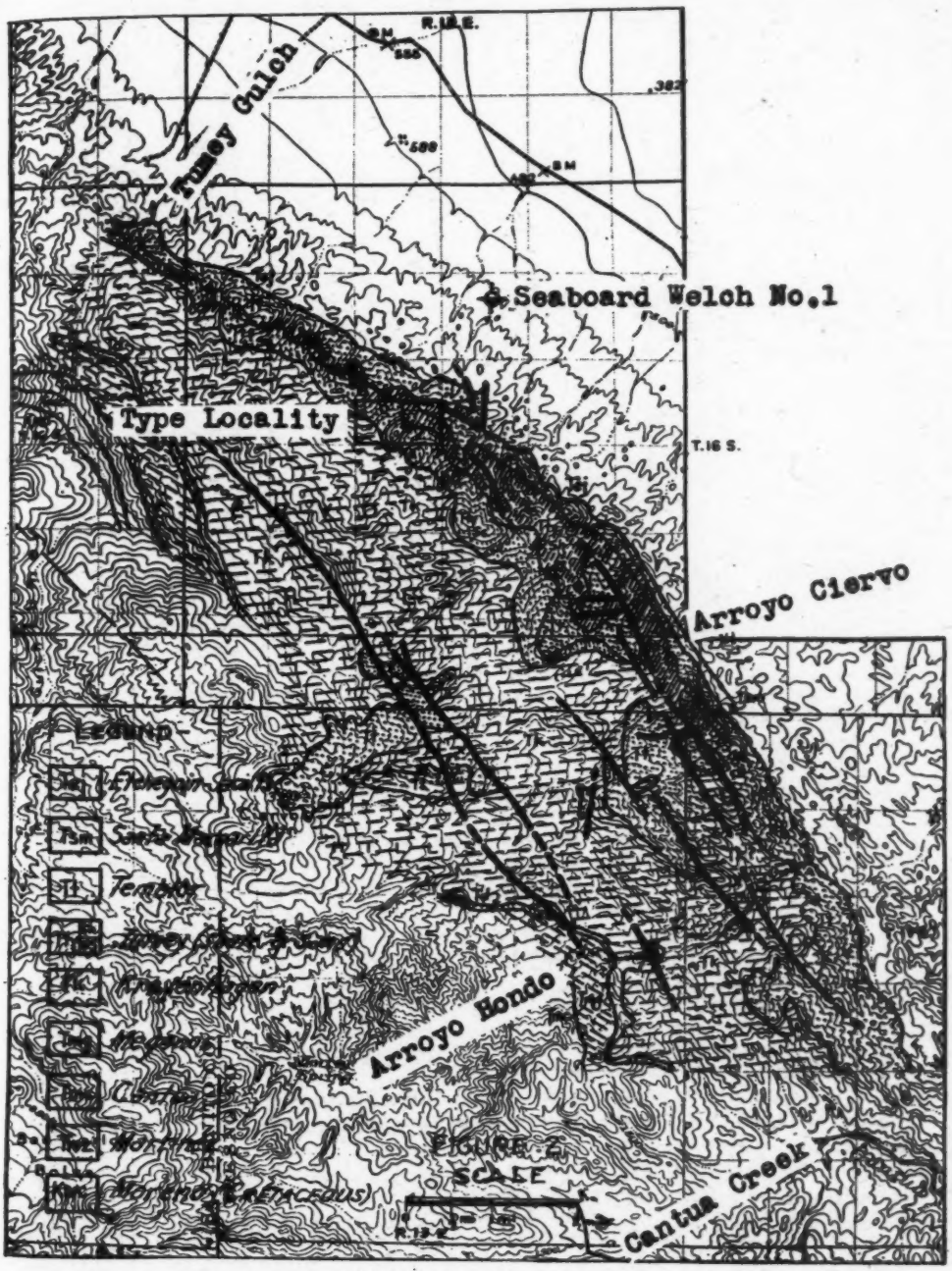


FIG. 2—Areal geologic map of the Ciervo Hill district (after Atwill, 1935). Location of type locality of Tumey formation and Seaboard Oil Co.'s "Welch" No. 1 well are indicated.

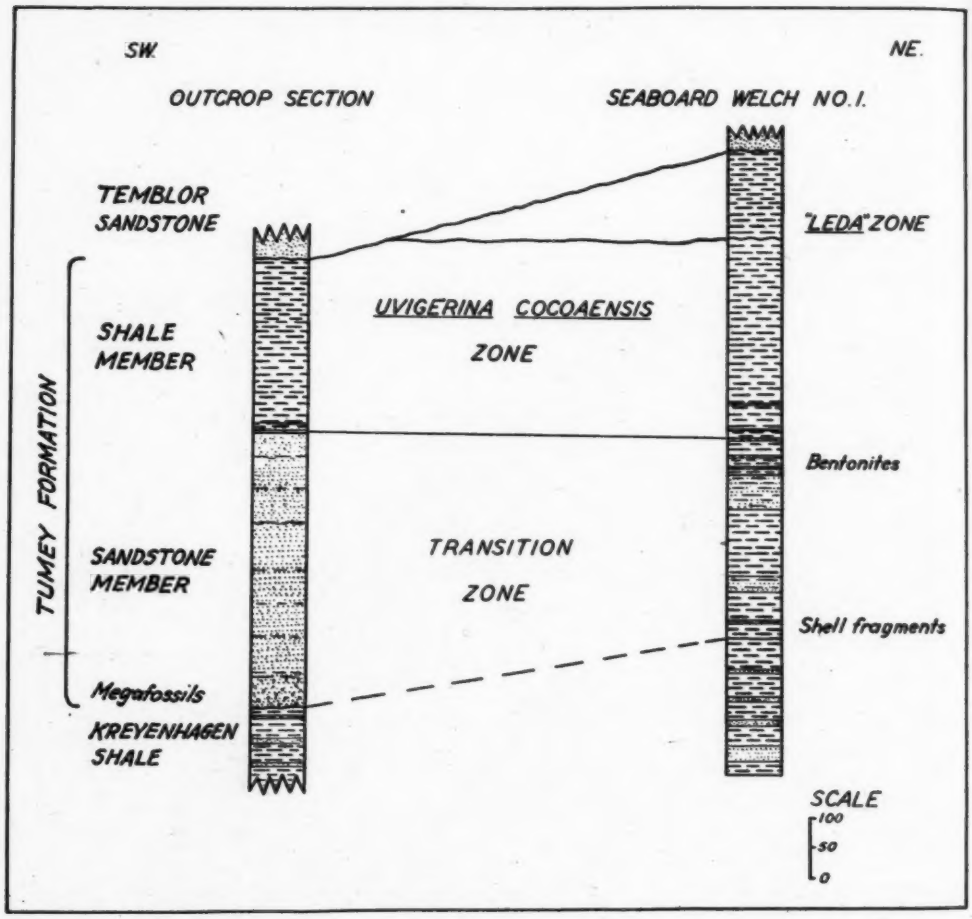


FIG. 3—Correlation of the outcrop section at the type locality of the Tumey formation (S. ½ sec. 16, T. 16 S., R. 13 E., M.D.M.) and the Seaboard "Welch" No. 1 well.

and blue bentonite are present in the lower part. The well section has an abundant well-developed foraminiferal faunule, which contains many of the species described from the Bassendorf and Keasey shales of Oregon by Cushman and Schenck (1928). Some of the characteristic Foraminifera of the *Uvigerina cocoaensis* zone are:

Bulimina lirata Cushman and Parker
Gyroidina condoni (Cushman and Schenck), var. *rotundiformis* n. var.
Planulina haydoni Cushman and Schenck
Uvigerina atwilli n. sp.
Uvigerina cocoaensis Cushman

In many samples, specimens of the genus *Uvigerina* comprise over two thirds of the faunule. There is a marked decrease in the abundance and number of species of *Uvigerina* in the underlying transition zone. *Bulimina lirata* Cushman and Parker, *Planulina haydoni* Cushman and Schenck, and *Planularia tolmani* n. sp., are commonly found in the lower part of the *Uvigerina cocoaensis* zone of the Seaboard Oil Co.'s Welch No. 1 well.

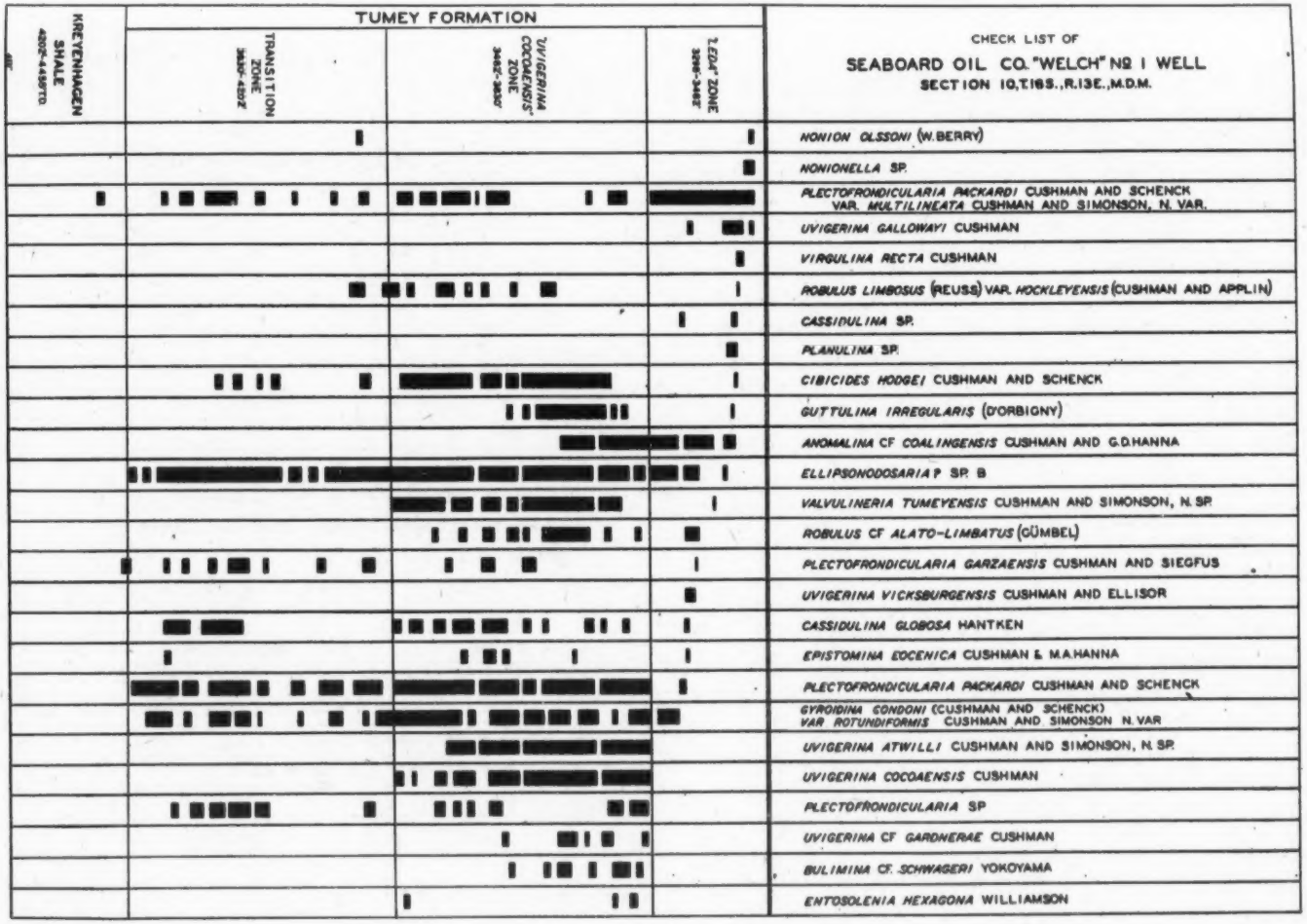

KREYENHAGEN SHALE
4202'-4498'TD
TUMEY FORMATION
TRANSITION ZONE
3636'-4202'
"UVIGERINA COCOAENSIS" ZONE
3462'-3636'
"LEDA" ZONE
3296'-3462'
CHECK LIST OF
SEABOARD OIL CO. "WELCH" NO 1 WELL
SECTION 10, T.16S., R.13E., M.D.M.
NONION OLSSONI (W.BERRY)
NONIONELLA SP.
PLECTOFRONDICULARIA PACKARDI CUSHMAN AND SCHENCK VAR. MULTILINEATA CUSHMAN AND SIMONSON, N. VAR.
UVIGERINA GALLOWAYI CUSHMAN
VIRGULINA RECTA CUSHMAN
ROBULUS LIMBOSUS (REUSS) VAR. HOCKLEYENSIS (CUSHMAN AND APPLIN)
CASSIDULINA SP.
PLANULINA SP.
CIBICIDES HODGEI CUSHMAN AND SCHENCK
GUTTULINA IRREGULARIS (D'ORBIGNY)
ANOMALINA CF COALINGENSIS CUSHMAN AND G.D.HANNA
ELLIPSONODOSARIA P SP. B
VALVULINERIA TUMEYENSIS CUSHMAN AND SIMONSON, N. SP.
ROBULUS CF ALATO-LIMBATUS (GÜMBEL)
PLECTOFRONDICULARIA GARZAENSIS CUSHMAN AND SIEGFUS
UVIGERINA VICKSBURGENSIS CUSHMAN AND ELLISOR
CASSIDULINA GLOBOSA HANTKEN
EPISTOMINA EOCENICA CUSHMAN & M.A.HANNA
PLECTOFRONDICULARIA PACKARDI CUSHMAN AND SCHENCK
GYROIDINA GONDONI (CUSHMAN AND SCHENCK) VAR ROTUNDIFORMIS CUSHMAN AND SIMONSON N.VAR
UVIGERINA ATWILLI CUSHMAN AND SIMONSON, N. SP.
UVIGERINA COCOAENSIS CUSHMAN
PLECTOFRONDICULARIA SP
UVIGERINA CF GARDNERAE CUSHMAN
BULIMINA CF. SCHWAGERI YOKOYAMA
ENTOSOLENIA HEXAGONA WILLIAMSON

FIG. 4

CHECK LIST OF
SEABOARD OIL CO. "WELCH" NO 1, WELL
SECTION 10, T.16S., R.13E., MDM.
TUMEY FORMATION
KREYENHAGEN SHALE
4202'-4435' TD.
TRANSITION ZONE
3630'-4202'
"UVIGERINA COCOAENSIS" ZONE
3482'-3630'
"LEDA" ZONE
3296'-3482'
ELLIPSONODOSARIA? SP. C.
ELLIPSONODOSARIA? SP. A.
GYROIDINA CF. SOLDANII D'ORBIGNY
SPIROLOCULINA WILCOXENSIS CUSHMAN AND GARRETT
ROBULUS ARTICULATUS (REUSS) VAR. TEXANUS (CUSHMAN AND APPLIN)
BOLIVINA JACKSONENSIS CUSHMAN AND APPLIN VAR. TUMEYENSIS CUSHMAN AND SIMONSON N. VAR.
PLANULARIA SP.
BOLIVINA JACKSONENSIS CUSHMAN AND APPLIN
ROBULUS CF. ARCUATO-STRIATUS (HANTKEN) VAR. CAROLINIANUS CUSHMAN
DENTALINA JACKSONENSIS (CUSHMAN AND APPLIN)
BULIMINA LIRATA CUSHMAN AND PARKER
PLANULARIA TOLMANI CUSHMAN AND SIMONSON N. SP.
ELLIPSONODOSARIA? SP. D.
ELLIPSONODOSARIA? SP. E.
BULIMINELLA BARBATI CUSHMAN AND SIMONSON N. SP.
PLANULINA HAYDONI CUSHMAN AND SCHENCK
BATHYSIPHON EOCENICA CUSHMAN AND G.D.HANNA
NODOGENERINA COOPERENSIS CUSHMAN
VALVULINERIA THOMASI CUSHMAN AND SIMONSON N. SP.
EPONIDES CF. UMBONATA (REUSS)
ROBULUS WELCHI CHURCH
UVIGERINA GARZAENSIS CUSHMAN AND SIEGFUS
EPONIDES DUPREI CUSHMAN AND SCHENCK VAR. CIERVOENSIS CUSHMAN AND SIMONSON N. VAR.
CIBICIDES CUSHMANI NUTTALL
CYCLAMMINA CF. SAMANICA W.BERRY
BOLIVINOPSIS DIRECTA (CUSHMAN AND SIEGFUS)

FIG. 5

TRANSITION ZONE

The transition zone in the Seaboard Oil Co.'s Welch No. 1 well consists of 321 feet (stratigraphic thickness) of brown diatomaceous shale with interbedded gray sand and thin streaks of dark blue bentonite. This zone was cored in the well section from 3830 to 4202 feet. The hybrid microfauna of the transition zone is essentially a mixture of Foraminifera that typically occur either in the overlying *Uvigerina cocoaensis* zone or the underlying restricted Kreyenhagen shale.[3]

The transition zone of the well section, predominantly shale, grades westward into the outcropping sandstone member of the Tumey formation. Fortunately, well-preserved Foraminifera were found just above the sandstone member in the outcrop section. This faunule is very similar to assemblages of the upper part of the transition zone of the well, indicating that this sandstone is approximately equivalent to the transition zone of the well section.

The transition zone has been recognized as far south as the Coalinga district but has not been found in the "Wagonwheel" formation (as used by G. C. Gester and John Galloway, 1933) at Devils Den.

CORRELATION AND AGE

Formations that are at least partially equivalent to the Tumey formation are: Gaviota, San Emigdio, Pleito (lower part), Wheatland, San Lorenzo, and "Wagonwheel" formations of California; the Eugene, Yaquina, Pittsburg Bluff, Tunnel Point, Fisher, Keasey, and Bassendorf formations of Oregon; and the "Gries Ranch" horizon and Lincoln formation of Washington.

Atwill (1935) stated that the mollusks found near the base of the sandstone member furnish evidence that the Tumey formation is Oliocene in age. Clark and Vokes (1936) have considered the Gaviota formation and its equivalents (Tumey formation, etc.) to constitute their uppermost Eocene Gaviota stage. Schenck and Kleinpell (1936) have included the Tumey formation within their Refugian stage, which is considered to be probably equivalent to a portion of the upper Eocene or lower Oligocene of Europe.

Affinities between Tumey Foraminifera and the uppermost Jackson Eocene faunules of the Gulf Coast is shown by the presence of identical species. Any exact correlation of the Tumey formation with the type European sections is hazardous, and it seems best to consider the Tumey as being Oligocene or Upper Eocene in age.

[3] Foraminifera from the restricted Kreyenhagen shale have been described in papers by Church (1931) and Cushman and Siegfus (1935), (1939), and (1942).

DESCRIPTIONS OF SPECIES

Family RHIZAMMINIDAE

Genus BATHYSIPHON M. Sars, 1872

BATHYSIPHON EOCENICA Cushman and G. D. Hanna

Plate 30, figure 1

Bathysiphon eocenica Cushman and G. D. Hanna, 1927, California Acad. Sci. Proc., ser. 4, vol. 16, p. 210, pl. 13, figs. 2, 3.

Bathysiphon cf. *B. eocenica* Cushman and McMasters, 1936, Jour. Paleontology, vol. 10, p. 508, pl. 74, fig. 1.

This species has already been recorded from the Eocene 7 miles north of Coalinga, California, and from the Llajas formation, Ventura, Co., California. Specimens evidently of this species occur in the transition zone and lower part of the *Uvigerina cocoaensis* zone.

Family LITUOLIDAE

Genus CYCLAMMINA H. B. Brady, 1876

CYCLAMMINA cf. C. SAMANICA W. Berry

Plate 30, figure 2

Specimens, somewhat resembling this species, described from the Eocene, Lobitos shales of Peru, occur in the lower part of the section. They are mostly crushed and distorted.

Family TEXTULARIIDAE

Genus TEXTULARIA Defrance, 1824

TEXTULARIA? sp.

Plate 30, figure 3

The figured specimen, which is the best one available, is incomplete. With the early stages missing it is difficult to be certain of the genus. It is such a peculiar form that it is placed on record until complete specimens are available.

FIG. 5

Family MILIOLIDAE
Genus SPIROLOCULINA d'Orbigny, 1826
SPIROLOCULINA WILCOXENSIS Cushman and Garrett
Plate 30, figures 4–6

Spiroloculina wilcoxensis Cushman and Garrett, 1939, Cushman Lab. Foram. Research Contr., vol. 15, p. 78, pl. 13, figs. 5, 6.

Specimens, apparently identical with this species, described from the Wilcox Eocene of Alabama, occur in considerable numbers with a fairly long range in the section. They are most abundant in the Kreyenhagen and the transition zone above it.

Family LAGENIDAE
Genus ROBULUS Montfort, 1808
ROBULUS cf. R. ALATO-LIMBATUS (Gümbel)
Plate 30, figure 8

A number of specimens in different parts of the section resemble this species, which is widely recorded and evidently variable. Many of the specimens are worn or broken, and well-preserved ones are rare.

ROBULUS LIMBOSUS HOCKLEYENSIS (Cushman and Applin)
Plate 30, figure 9

Cristellaria limbosa hockleyensis Cushman and Applin, 1926, Am. Assoc. Petroleum Geologists Bull., vol. 10, p. 171, pl. 8, figs. 3a, b, 4.

Robulus limbosus hockleyensis Ellisor, 1933, Am. Assoc. Petroleum Geologists Bull., vol. 17, no. 11, pl. 1, figs. 11a, b.—Cushman and Dusenbury, 1934, Cushman Lab. Foram. Research Contr., vol. 10, p. 52, pl. 7, fig. 1.—Cushman, 1935, U. S. Geol. Survey Prof. Paper 181, p. 16, pl. 4, figs. 15a, b; pl. 6, figs. 3a, b.—Cushman, 1939, Cushman Lab. Foram. Research Contr., vol. 15, p. 53, pl. 9, fig. 21.

Rather typical specimens occur in the middle portion of the section, but, like many of the specimens of *Robulus* in this material, the majority of them are more or less broken.

ROBULUS cf. R. ARCUATO-STRIATUS CAROLINIANUS Cushman
Plate 30, figure 10

A few specimens similar to that figured are close to this Eocene species.

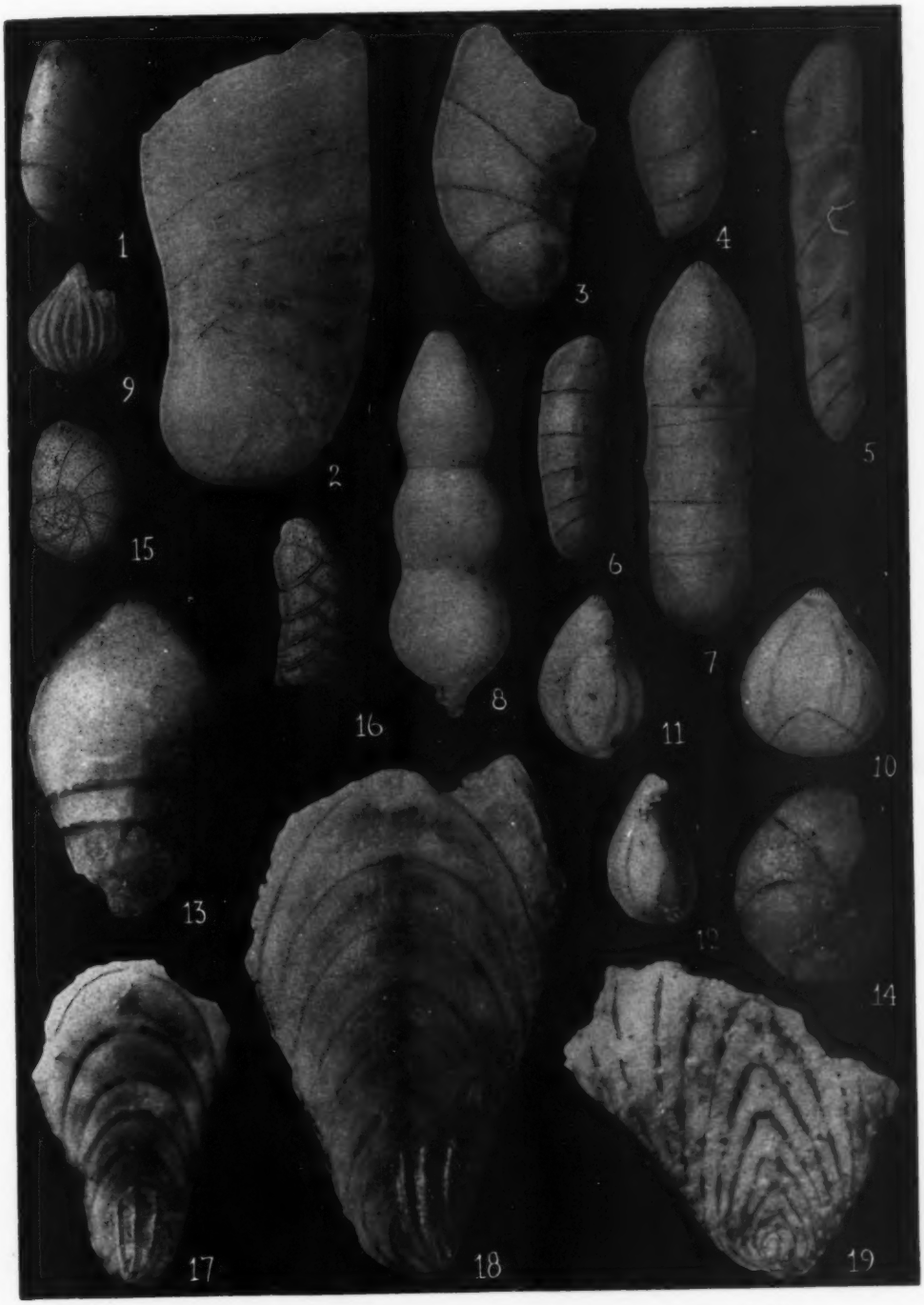
ROBULUS ARTICULATUS TEXANUS (Cushman and Applin)
Plate 30, figure 7

Cristellaria articulata Reuss var. *texana* Cushman and Applin, 1926, Am. Assoc. Petroleum Geologists Bull., vol. 10, p. 170, pl. 8, figs. 1a, b, 2.
Robulus articulatus (Reuss) var. *texanus* Ellisor, 1933, Am. Assoc. Petroleum Geologists Bull., vol. 17, no. 11, pl. 2, fig. 3.—Cushman and Dusenbury, 1934, Cushman Lab. Foram. Research Contr., vol. 10, p. 53, pl. 7, figs. 2a, b, 3a, b.—Cushman, 1935, U. S. Geol. Survey Prof. Paper 181, p. 16, pl. 4, figs. 16a, b, 17.

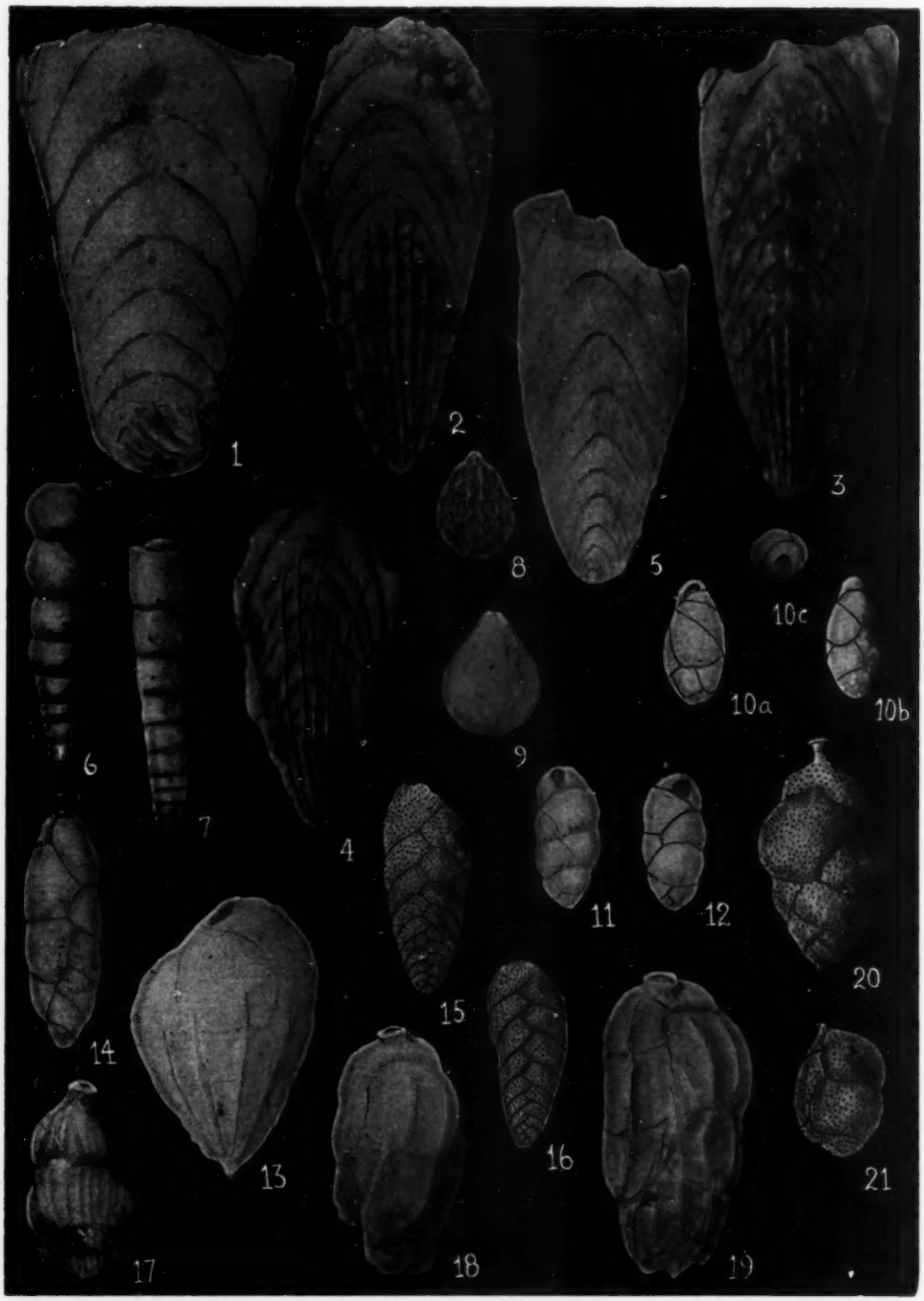
EXPLANATION OF PLATE 31

(All magnifications ×90)

FIGS. *1–4—Marginulina* sp. Tumey formation, in Seaboard Oil Co.'s "Welch" No. 1 well, Fresno Co., Calif. *1*, From 3800-foot sample. *2*, From 3550-foot sample. *3*, From 3585-foot sample. *4*, From 3738-foot sample. (p. 196)
5–7—Dentalina cooperensis Cushman. Tumey formation. *5*, From 3800-foot sample. *6*, From 3720-foot sample. *7*, From 3638-foot sample. (p. 196)
8—Dentalina jacksonensis (Cushman and Applin). Tumey formation, from 3870-foot sample. (p. 196)
9—Lagena cf. *L. acuticosta* Reuss. Tumey formation, from 3410-foot sample. (p. 196)
10–12—Guttulina irregularis (d'Orbigny). Tumey formation. *10*, *11*, From 3345-foot sample. *12*, From 3560-foot sample. (p. 196)
13—Pseudoglandulina sp. Tumey formation, from 3815-foot sample. (p. 196)
14—Nonion olssoni (W. Berry). Tumey formation, from 3870-foot sample. (p. 196)
15—Nonionella sp. Tumey formation, from 3318-foot sample. (p. 196)
16—Bolivinopsis directa (Cushman and Siegfus). Kreyenhagen shale, from 4205-foot sample. (p. 197)
17, 18—Plectofrondicularia packardi Cushman and Schenck. Tumey formation. *17*, From 3775-foot sample. *18*, From 3525-foot sample. (p. 197)
19—Plectofrondicularia garzaensis Cushman and Siegfus. Tumey formation, from 3398-foot sample. (p. 197)



Cushman and Simonson, Eocene and Oligocene Foraminifera



Cushman and Simonson, Eocene and Oligocene Foraminifera

Lenticulina articulata (Reuss) var. *texana* Howe and Wallace, 1932, Louisiana Dept. Cons. Geol. Bull. 2, p. 31, pl. 5, figs. 1, 2.

This variety, already known from the Eocene of South Carolina, Louisiana, Texas, and California, occurs in the section but shows some variation.

ROBULUS WELCHI Church
Plate 30, figure 11

Robulus welchi Church, 1931, California Div. Mines, vol. 27, p. 212, pl. C, figs. 13, 14, 1941; l. c., Bull. 118, p. 182.

This species, originally described from the Eocene, Kreyenhagen, of California, occurs in the lower part of the well section.

Genus LENTICULINA Lamarck, 1804
LENTICULINA cf. L. CONVERGENS (Bornemann)
Plate 30, figure 12

A few specimens in the section resemble this species, but well-preserved specimens are rare.

Genus PLANULARIA Defrance, 1824
PLANULARIA TOLMANI Cushman and Simonson, n. sp.
Plate 30, figures 13, 14

Test about twice as long as broad, strongly compressed laterally, periphery subacute, slightly keeled; chambers distinct, not inflated, increasing rather evenly in size as added; sutures distinct, strongly limbate but not raised, of clear shell material, with a distinct angle near the periphery; wall smooth; aperture terminal, radiate, somewhat in from the periphery.

Length of holotype, 0.78 mm.; breadth, 0.40 mm.; thickness, 0.15 mm.

Holotype (Cushman Coll. No. 38546) from the Tumey formation, at a depth of 3720 feet, in Seaboard Oil Co.'s Welch No. 1 well, Fresno Co., Calif.

This species differs from *P. markleyana* Church in the subacute keeled periphery and distinctly angled sutures.

PLANULARIA sp.
Plate 30, figure 16

The figured specimen shows the charac-

EXPLANATION OF PLATE 32

(All magnifications ×90, except figs. 8, 9)

FIGS. *1*—*Plectofrondicularia packardi* Cushman and Schenck. Tumey formation, at a depth of 3525 feet, in Seaboard Oil Co.'s "Welch" No. 1 well, Fresno Co., Calif. (p. 197)

2-4—*Plectofrondicularia packardi multilineata* Cushman and Simonson, n. var. Tumey formation. *2*, Paratype, from 3330-foot sample. *3*, Paratype, from 3340-foot sample. *4*, Holotype, from 4145-foot sample. (p. 197)

5—*Plectofrondicularia* sp. Tumey formation, from 3525-foot sample. (p. 197)

6, *7*—*Nodogenerina cooperensis* Cushman. Tumey formation. *6*, From 4065-foot sample. *7*, From 3860-foot sample. (p. 197)

8—*Entosolenia hexagona* Williamson. Tumey formation, from 3815-foot sample. ×130. (p. 198)

9—*Entosolenia globosa* (Montagu). Tumey formation, from 3870-foot sample. ×130. (p. 198)

10—*Buliminella barbati* Cushman and Simonson, n. sp. Tumey formation, from 3735-foot sample. Holotype, *a*, front view, *b*, rear view, *c*, apertural view. (p. 197)

11, 12—*Bulimina* cf. *B. schwageri* Yokoyama. Tumey formation, from 3478-foot sample. (p. 198)

13—*Bulimina lirata* Cushman and Parker. Tumey formation, from 3770-foot sample. (p. 198)

14—*Virgulina recta* Cushman. Tumey formation, from 3332-foot sample. (p. 198)

15—*Bolivina jacksonensis* Cushman and Applin. Tumey formation, from 3970-foot sample. (p. 198)

16—*Bolivina jacksonensis tumeyensis* Cushman and Simonson, n. var. Tumey formation, from 3600-foot sample. Holotype. (p. 199)

17—*Uvigerina* cf. *U. gardnerae* Cushman. Tumey formation, from 3525-foot sample. (p. 200)

18, 19—*Uvigerina gallowayi* Cushman. Tumey formation. *18*, From 3345-foot sample. *19*, From 3338-foot sample. (p. 200)

20, 21—*Uvigerina garzaensis* Cushman and Siegfus. Tumey formation. *20*, From 4010-foot sample. *21*, From 3872-foot sample. (p. 199)

ters of a species very rare in the well-samples. It is a large and striking species somewhat resembling *P. catahoulaensis* Howe and Wallace from the Jackson Eocene, Louisiana, but evidently not the same. It also resembles the figure of *Robulus articulatus texanus* (Cushman and Applin) from the Eocene of Texas (1935 pl. 4, figs. 16a, b). No complete specimens were found.

Genus MARGINULINA d'Orbigny, 1826
MARGINULINA sp.
Plate 30, figure 15; plate 31, figures 1–4

A few, mostly incomplete, specimens may be assigned to *Marginulina* but the material is insufficient to warrant specific identification. They evidently represent several species and are here figured for future reference.

Genus DENTALINA d'Orbigny, 1826
DENTALINA COOPERENSIS Cushman
Plate 31, figures 5–7

Dentalina cooperensis Cushman, 1933, Cushman Lab. Foram. Research Contr., vol. 9, p. 8, pl. 1, fig. 17.—Cushman, 1935, U. S. Geol. Survey Prof. Paper 181, p. 20, pl. 8, figs. 3, 4.

Some of the specimens figured here do not have a basal spine but otherwise seem to be fairly typical of this species characteristic of the Jackson Eocene.

DENTALINA JACKSONENSIS
(Cushman and Applin)
Plate 32, figure 8

Nodosaria jacksonensis Cushman and Applin, 1926, Am. Assoc. Petroleum Geologists Bull., vol. 10, p. 170, pl. 7, figs. 14–16.—Cushman, 1927, Jour. Paleontology, vol. 1, p. 153, pl. 24, fig. 3.—Cole, 1928, Bulls. Am. Paleontology, vol. 14, no. 53, p. 208, pl. 3, fig. 12.

Nodosaria cf. *N. jacksonensis* Cole and Ponton, 1930, Florida Geol. Survey Bull. 5, p. 33, pl. 6, fig. 1.

Dentalina jacksonensis Cushman and Ponton, 1932, Cushman Lab. Foram. Research Contr., vol. 8, p. 55, pl. 7, figs. 10, 11.—Cushman, 1935, U. S. Geol. Survey Prof. Paper 181, p. 20, pl. 8, figs. 7–9.—Cushman and McMasters, 1936, Jour. Paleontology, vol. 10, p. 511, pl. 75, figs. 3–5.—Coryell and Embich, 1937, l. c., vol. 11, p. 298, pl. 42, fig. 8.—Toulmin, 1941, l. c., vol. 15, p. 585, pl. 79, fig. 16.

Dentalina cf. *D. jacksonensis* Howe, 1939, Louisiana Dept. Cons. Geol. Bull. 14, p. 44, pl. 6, fig. 2.

This is a widely distributed species in the North American Eocene. The figured specimen is megalospheric.

Genus PSEUDOGLANDULINA Cushman, 1929
PSEUDOGLANDULINA sp.
Plate 31, figure 13

The figured specimen is a species very rare in the well samples. The early chambers are obscure. The aperture is radiate.

Genus LAGENA Walker and Jacob, 1798
LAGENA cf. L. ACUTICOSTA Reuss
Plate 31, figure 9

Very rare specimens with distinct longitudinal costae are included under this name. They show considerable variation in shape and the number of costae.

Family POLYMORPHINIDAE
Genus GUTTULINA d'Orbigny, 1826
GUTTULINA IRREGULARIS (d'Orbigny)
Plate 31, figures 10–12

From the records this species evidently has a long time-range. The form described and recorded as *Polymorphina byramensis* Cushman and later recorded by Cushman and Schenck as *Guttulina byramensis* from the Bassendorf shale of Oregon is probably to be included under d'Orbigny's species.

Family NONIONIDAE
Genus NONION Montfort, 1808
NONION OLSSONI (W. Berry)
Plate 31, figure 14

Nonionina olssoni W. Berry, 1928, Eclogae geol. Helvetiae, vol. 21, p. 403, text figs. 23a–c.

Nonion olssoni Cushman, 1939, U. S. Geol. Survey Prof. Paper 191, p. 7, pl. 1, figs. 29a–c, 30a, b.

The types of this species are from the upper Eocene, middle Lobitos shales, of northwestern Peru. It has also been recorded from the Eocene, Chapapote formation, of Mexico and from well samples of Jackson Eocene age from Texas.

Genus NONIONELLA Cushman, 1926
NONIONELLA sp.
Plate 31, figure 15

The figured specimen does not seem to be identical with any described species. There are not enough specimens, however, to warrant a full description.

Family HETEROHELICIDAE
Genus BOLIVINOPSIS Yakovlev, 1891
BOLIVINOPSIS DIRECTA (Cushman and Siegfus)
Plate 31, figure 16

Spiroplectoides directa Cushman and Siegfus, 1939, Cushman Lab. Foram. Research Contr., vol. 15, p. 26, pl. 6, figs. 7, 8a, b.

The types of this species are from the Eocene, Kreyenhagen shale, upper Garza Creek, California, 104 feet below the top of the Kreyenhagen. Typical specimens occur near the top of the Kreyenhagen as it is correlated in the well.

Genus PLECTOFRONDICULARIA Liebus, 1903
PLECTOFRONDICULARIA GARZAENSIS Cushman and Siegfus
Plate 31, figure 19

Plectofrondicularia garzaensis Cushman and Siegfus, 1939, Cushman Lab. Foram. Research Contr., vol. 15, p. 26, pl. 6, fig. 9.

Like the preceding, this species was described from the Eocene, Kreyenhagen shale of Garza Creek, California. The specimens from the lower part of the section are identical with the types.

PLECTOFRONDICULARIA PACKARDI Cushman and Schenck
Plate 31, figures 17, 18; plate 32, figure 1

Plectofrondicularia packardi Cushman and Schenck, 1928, Univ. California Publ., Bull. Dept. Geol. Sci., vol. 17, p. 311, pl. 43, figs. 14, 15,—Condit, 1930, Jour. Paleontology, vol. 4, p. 260 (list).

This species was originally described from the Bassendorf shale of Oregon and has been listed from the Eocene, Kreyenhagen shale, of California by Condit. Typical specimens occur in several parts of the well section and all have the characteristic costae at the base and the peculiarly curved sutures of this species.

PLECTOFRONDICULARIA PACKARDI MULTILINEATA Cushman and Simonson, n. var.
Plate 32, figures 2–4

Variety differing from typical form in the longer, more numerous, and thinner costae.

Holotype of variety (Cushman Coll. No. 38569) from the Tumey formation, at a depth of 4145 feet, in Seaboard Oil Co.'s Welch No. 1 well, Fresco Co., Calif.

The character of the sutures is similar to that of the typical form of the species, and, although the ornamentation is very different, the two forms seem to be definitely related.

PLECTOFRONDICULARIA sp.
Plate 32, figure 5

The specimen figured is smooth and narrowly tapering, unlike the forms of *P. packardi*, and the sutures are more oblique and less rounded. Only a few incomplete specimens were found.

Genus NODOGENERINA Cushman, 1927
NODOGENERINA COOPERENSIS Cushman
Plate 32, figures 6, 7

Nodogenerina cooperensis Cushman, 1933, Cushman Lab. Foram. Research Contr., vol. 9, p. 11, pl. 1, fig. 27.—Cushman, 1935, U. S. Geol. Survey Prof. Paper 181, p. 34, pl. 12, fig. 13.—Coryell and Embich, 1937, Jour. Paleontology, vol. 11, p. 303, pl. 42, fig. 16.

This species has been recorded from the upper Eocene of South Carolina and Panama. The specimens from the well samples are very similar to the types.

Family BULIMINIDAE
Genus BULIMINELLA Cushman, 1911
BULIMINELLA BARBATI Cushman and Simonson, n. sp.
Plate 32, figure 10

Test fusiform, 2½ to 3 times as long as broad, of 3 to 4 whorls, greatest breadth usually at or below middle, initial end rounded, last whorl much constricted at apertural end; chambers distinct, little if at all inflated, about 5 to a whorl; sutures very slightly depressed; wall smooth; aperture broadly loop-shaped in an obliquely truncate apertural face.

Length, 0.30 to 0.33 mm.; diameter, 0.15 mm.

Holotype (Cushman Coll. No. 38574) from the Tumey formation, at a depth of 3735 feet, in Seaboard Oil Co.'s Welch No. 1 well, Fresco Co., Calif.

This species differs from *B. brevior* Cushman in the more elongate form, larger number of whorls, rounded base, and more truncate apertural face. It is named in honor of W. F. Barbat of the Standard Oil Co. of California.

Genus BULIMINA d'Orbigny, 1826
BULIMINA cf. B. SCHWAGERI Yokoyama
Plate 32, figures 11, 12

The elongate specimens figured represent a species close to that of Yokoyama from the "Cretaceous" of Japan (Palaeontographica, vol. 36, p. 190, pl. 24, figs. 6a, b, 7a, b, 8a, b, 1890). The chambers are inflated, few to a whorl, the whole test elongate with nearly parallel sides, and the apertural face high and semicircular.

BULIMINA LIRATA Cushman and Parker
Plate 32, figure 13

Bulimina lirata Cushman and Parker, 1936, Cushman Lab. Foram. Research Contr., vol. 12, p. 43, pl. 8, figs. 2a–c.

The types of this species are from the Eocene of Coal Mine Canyon, Fresno County, California. The present specimens have been compared with the types and seem to be identical.

Genus ENTOSOLENIA Ehrenberg, 1848
ENTOSOLENIA HEXAGONA Williamson
Plate 32, figure 8

A very few specimens with hexagonal raised ornamentation may be included under this species.

ENTOSOLENIA GLOBOSA (Montagu)
Plate 32, figure 9

Specimens referable to this species are very rare, occurring only in the transition zone.

Genus VIRGULINA d'Orbigny, 1826
VIRGULINA RECTA Cushman
Plate 32, figure 14

Virgulina sp. Cushman, 1922, U. S. Geol. Survey Prof. Paper 129-E, p. 92, pl. 16, figs. 2a, b, 3.
Virgulina recta Cushman, 1933, Cushman Lab. Foram. Research Contr., vol. 9, p. 12, pl. 1, figs. 31a, b.—Cushman, 1935, U. S. Geol. Survey Prof. Paper 181, p. 36, pl. 14, figs. 4a, b. —Cushman, 1937, Cushman Lab. Foram. Research Special Pub. 9, p. 8, pl. 1, figs. 23a, b.

This species is a characteristic one of the upper Eocene of the southeastern United States. The specimens from the California material seem identical. In the section it seems to be limited to the *Leda* zone.

Genus BOLIVINA d'Orbigny, 1839
BOLIVINA JACKSONENSIS Cushman and Applin
Plate 32, figure 15

Bolivina sp. Cushman, 1923, U. S. Geol. Survey Prof. Paper 133, p. 19, pl. 3, fig. 2.
Bolivina jacksonensis Cushman and Applin, 1926 Am. Assoc. Petroleum Geologists Bull., vol. 10

EXPLANATION OF PLATE 33

(All magnifications ×90)

FIGS. *1*—*Uvigerina cocoaensis* Cushman. Tumey formation, at a depth of 3800 feet, in Seaboard Oil Co.'s "Welch" No. 1 well, Fresno Co., Calif. (p. 199)

2–4—*Uvigerina atwilli* Cushman and Simonson, n. sp. Tumey formation. *2*, Holotype, from 3615-foot sample. *3*, Paratype, from 3610-foot sample. *4*, Paratype, from 3500-foot sample. (p. 200)

5—*Uvigerina vicksburgensis* Cushman and Ellisor. Tumey formation from 3405-foot sample. (p. 200)

6, *7*—*Ellipsonodosaria?* sp. A. Tumey formation. *6*, From 3520-foot sample. *7*, From 3920-foot sample. (p. 200)

8, *9*—*Ellipsonodosaria?* sp. B. Tumey formation. *8*, From 3474-foot sample. *9*, From 3410-foot sample. (p. 200)

10—*Ellipsonodosaria?* sp. C. Tumey formation, from 3560-foot sample. (p. 200)

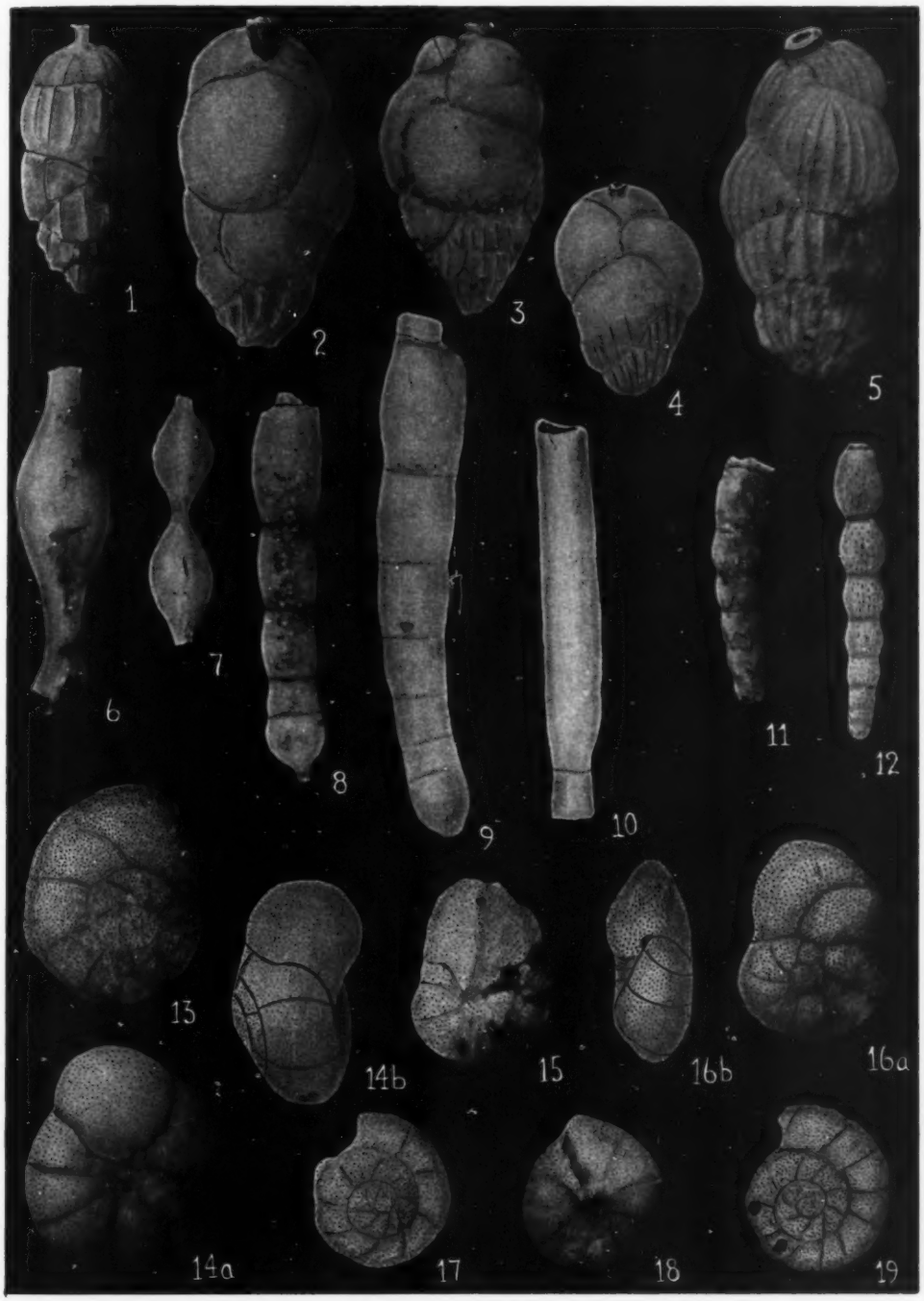
11—*Ellipsonodosaria?* sp. D. Tumey formation, from 3640-foot sample. (p. 201)

12—*Ellipsonodosaria?* sp. E. Tumey formation, from 3655-foot sample. (p. 201)

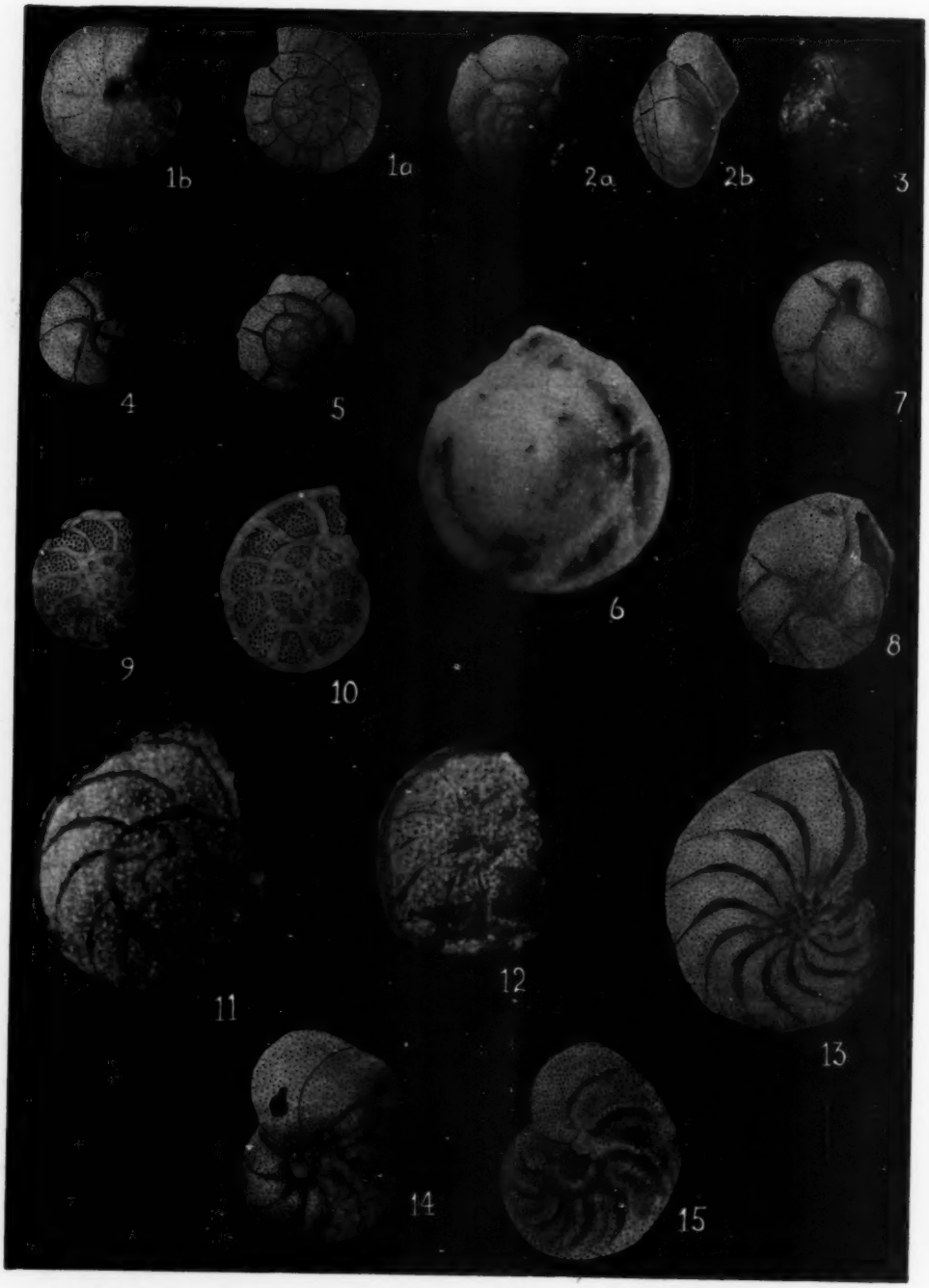
13, *14*—*Valvulineria tumeyensis* Cushman and Simonson, n. sp. Tumey formation, from 3525-foot sample. *13*, Holotype, dorsal view. *14*, Paratype, *a*, ventral view, *b*, peripheral view. (p. 201)

15, *16*—*Valvulineria thomasi* Cushman and Simonson, n. sp. Tumey formation, from 4069-foot sample. *15*, Paratype, ventral view. *16*, Holotype, *a*, dorsal view, *b*, peripheral view. (p. 201)

17–19—*Gyroidina condoni rotundiformis* Cushman and Simonson, n. var. Tumey formation, from 3555-foot sample. *17*, Paratype, dorsal view. *18*, Paratype, ventral view. *19*, Holotype, dorsal view. ×90. (p. 201)



Cushman and Simonson, Eocene and Oligocene Foraminifera



Cushman and Simonson, Eocene and Oligocene Foraminifera

p. 167, pl. 7, figs. 3a, b, 4a, b.—Cole, 1928, Bulls. Am. Paleontology, vol. 14, no. 53, p. 212, 1928.—Howe and Wallace, 1932, Louisiana Dept. Cons. Geol. Bull. 2, p. 58, pl. 11, fig. 11, —Ellisor, 1933, Am. Assoc. Petroleum Geologists Bull., vol. 17, no. 11, pl. 3, fig. 3.—Cushman, 1935, U. S. Geol. Survey Prof. Paper 181, p. 37, pl. 14, figs. 11a, b, 12, 13a, b.—Cushman, 1937, Cushman Lab. Foram. Research Special Pub. 9, p. 57, pl. 7, figs. 17a, b, 18a–c.—Galloway and Heminway, 1941, New York Acad. Sci., Sci. Survey Porto Rico and Virgin Islands, vol. 3, p. 418, pl. 30, figs. 8a, b.

This is a characteristic species of the upper Eocene and lower Oligocene. It is known from the Coastal Plain region of the southeastern United States, Porto Rico, and Mexico.

BOLIVINA JACKSONENSIS TUMEYENSIS Cushman and Simonson, n. var.
Plate 32, figure 16

Variety differing from typical form in the more compressed test, slight peripheral keel, and more distinctly limbate sutures.

Holotype of variety (Cushman Coll. No. 38581) from the Tumey formation, at a depth of 3600 feet, in Seaboard Oil Co.'s Welch No. 1 well, Fresno Co., Calif.

There are several other Bolivinas in the material but they are represented by too few or too poorly preserved specimens to warrant specific identification.

Genus UVIGERINA d'Orbigny, 1826

UVIGERINA GARZAENSIS Cushman and Siegfus
Plate 32, figures 20, 21

Uvigerina garzaensis Cushman and Siegfus, 1939, Cushman Lab. Foram. Research Contr., vol. 15, p. 28, pl. 6, figs. 15a, b.

This species was described from the Eocene, Kreyenhagen shale, of Garza Creek, California. It is fairly common in the lower part of the well section in the Kreyenhagen and the transition zone above it. With these are a few costate forms somewhat like *U. churchi* Cushman and Siegfus also described from the Kreyenhagen.

UVIGERINA COCOAENSIS Cushman
Plate 33, figure 1

Uvigerina cocoaensis Cushman, 1925, Cushman Lab. Foram. Research Contr., vol. 1, pt. 3, p. 68, pl. 10, fig. 12.—Cushman and Schenck, 1928, Univ. California Publ., Bull. Dept. Geol. Sci., vol. 17, p. 312, pl. 43, figs. 17–19.—Cushman, 1935, U. S. Geol. Survey Prof. Paper 181, p. 39, pl. 15, figs. 11–13.—Nuttall, 1935, Jour. Paleontology, vol. 9, p. 127, pl. 15, fig. 5.—Cushman and Edwards, 1937, Cushman Lab. Foram. Research Contr., vol. 13, p. 76, pl. 11, figs. 8, 9; idem, vol. 14, p. 89, pl. 14, figs. 15–17, 1938.

This is a variable species, as a study of a large series from the type material shows. The material from the well samples seems

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EXPLANATION OF PLATE 34

(All magnifications ×90.)

FIGS. *1*—*Gyroidina* cf. *G. soldanii* d'Orbigny. Tumey formation, at a depth of 3552–58 feet, in Seaboard Oil Co.'s "Welch" No. 1 well, Fresno Co., Calif. *a*, Dorsal view, *b*, ventral view. (p. 201)

2, 3—*Eponides dupréi ciervoensis* Cushman and Simonson, n. var. Tumey formation, from 3970-foot sample. *2*, Holotype, *a*, dorsal view, *b*, peripheral view. *3*, Paratype, ventral view. (p. 201)

4, 5—*Eponides* cf. *E. umbonata* (Reuss). Tumey formation, from 3760-foot sample. *4*, Ventral view. *5*, Dorsal view. (p. 201)

6—*Epistomina eocenica* Cushman and M. A. Hanna. Tumey formation, from 3570-foot sample. (p. 202)

7—*Cassidulina globosa* Hantken. Tumey formation, from 3734–43-foot sample. (p. 202)

8—*Cassidulina* sp. Tumey formation, from 3340-foot sample. (p. 202)

9, 10—*Anomalina* cf. *A. coalingensis* Cushman and G. D. Hanna. Tumey formation. *9*, From 3396-foot sample. *10*, From 3474-foot sample. (p. 202)

11, 12—*Planulina haydoni* Cushman and Schenck. Tumey formation, from 3720-foot sample. (p. 202)

13—*Planulina* sp. Tumey formation, from 3350-foot sample. (p. 202)

14, 15—*Cibicides hodgei* Cushman and Schenck. Tumey formation, from 3340-foot sample. (p. 202)

to come within the range of variation of the species. It is abundant in the upper Eocene of the southeastern Coastal Plain area of the United States and apparently extends into the Oligocene in some areas.

UVIGERINA ATWILLI Cushman and Simonson, n. sp.
Plate 33, figures 2–4

Test elongate, fusiform, greatest breadth in adult at about middle, rounded in section, initial end rounded, apertural end truncate; chambers distinct, inflated in later whorls; sutures distinct, depressed in later portion; walls of early chambers ornamented with a few, platelike costae, those of each chamber independent of adjacent ones, gradually disappearing before middle portion of test is developed, remainder of test smooth; aperture with short cylindrical neck, slightly developed lip, in a depression of truncate apertural end.

Length, 0.68 to 0.80 mm.; diameter, 0.38 to 0.43 mm.

Holotype (Cushman coll. No. 38585) from the Tumey formation, at a depth of 3615 feet, in Seaboard Oil Co.'s Welch No. 1 well, Fresno Co., Calif.

This species differs from *Uvigerina glabrans* Cushman in the more fusiform shape, more inflated chambers, shorter neck and more truncated apertural end. It shows considerable variation in the amount of development of the costae. The species is named in honor of E. R. Atwill of the Union Oil Co. of California who named the Tumey formation.

UVIGERINA cf. U. GARDNERAE Cushman
Plate 32, figure 17

A few specimens, mostly immature, resemble this species of the upper Eocene.

UVIGERINA GALLOWAYI Cushman
Plate 32, figures 18, 19

Uvigerina gallowayi Cushman, 1929, Cushman Lab. Foram. Research Contr., vol. 5, p. 94, pl. 13, figs. 33, 34.—Cushman and Edwards, 1938, l. c., vol. 14, p. 75, pl. 13, figs. 8, 9.—Kleinpell, 1938, Am. Assoc. Petroleum Geologists, p. 294, pl. 5, figs. 1, 2, 5.—Cushman and Todd, 1941, Cushman Lab. Foram. Research Contr., vol. 17, p. 45, pl. 13, fig. 11.—Galloway and Heminway, 1941, New York Acad. Sci., Sci. Survey Porto Rico and Virgin Islands, vol. 3, p. 429, pl. 33, fig. 8.

This species, known from the upper Oligocene and lower Miocene, occurs in typical form in the well samples. In some specimens the basal costae are highly developed to platelike form and resemble *Uvigerina cubana* Palmer and Bermúdez from the Oligocene of Cuba.

UVIGERINA VICKSBURGENSIS Cushman and Ellisor
Plate 33, figure 5

Uvigerina vicksburgensis Cushman and Ellisor, 1931, Cushman Lab. Foram. Research Contr., vol. 7, p. 54, pl. 7, figs. 7a, b.—Ellisor, 1933, Am. Assoc. Petroleum Geologists Bull., vol. 17, no. 11, pl. 3, figs. 10a, b.—Cushman and Edwards, 1938, Cushman Lab. Foram. Research Contr., vol. 14, p. 76, pl. 13, figs. 10a, b, 11.—Galloway and Heminway, 1941, New York Acad. Sci., Sci. Survey Porto Rico and Virgin Islands, vol. 3, p. 432, pl. 33, figs. 12a, b.

Records of this species are from the Oligocene of the Gulf coastal region and Mexico, with somewhat less typical specimens from the upper Oligocene or lower Miocene of the Porto Rico region.

Family ELLIPSOIDINIDAE
Genus ELLIPSONODOSARIA A. Silvestri, 1900
ELLIPSONODOSARIA? sp. A
Plate 33, figures 6, 7

Fragments of an elongate form with contracted necks between the chambers probably belong to *Ellipsonodosaria*. They resemble specimens that have been referred to "*Nodosaria pyrula*" and other species, but no complete specimens were found.

ELLIPSONODOSARIA? sp. B
Plate 33, figures 8, 9

From what may be seen of the apertural ends in the broken specimens figured, these may belong to *Ellipsonodosaria*. Specimens with and without the basal spine are similar in other characters.

ELLIPSONODOSARIA? sp. C
Plate 33, figure 10

Single broken chambers of an elongate cylindrical form occurred frequently in the material.

ELLIPSONODOSARIA? sp. D
Plate 33, figure 11

This is a peculiarly ornamented species with a series of coarse toothlike projections near the base of the chambers. No complete specimens were found.

ELLIPSONODOSARIA? sp. E
Plate 33, figure 12

This very rare species has a very finely spinose surface.

Family ROTALIIDAE
Genus VALVULINERIA Cushman, 1926
VALVULINERIA TUMEYENSIS Cushman and Simonson, n. sp.
Plate 33, figures 13, 14

Test biconvex, ventral side more strongly so, periphery broadly rounded; chambers distinct, especially in last-formed whorl, 6 to 8 in adult whorl; sutures distinct, earlier ones somewhat limbate, later ones slightly depressed; wall distinctly, rather coarsely perforate; aperture ventral, low, opening into umbilical cavity, with definite lip.

Diameter, 0.50 to 0.55 mm.; height, 0.38 mm.

Holotype (Cushman Coll. No. 38599) from the Tumey formation, at a depth of 3970 feet, in Seaboard Oil Co.'s Welch No. 1 well, Fresno Co., Calif.

This species differs from *Valvulineria advena* Cushman and Siegfus in the larger number of chambers, more open whorls, and coarser perforations of the wall.

VALVULINERIA THOMASI Cushman and Simonson, n. sp.
Plate 33, figures 15, 16

Test unequally biconvex, dorsal side nearly flat, ventral side strongly convex, periphery slightly rounded to subacute, ventral side somewhat umbilicate; chambers distinct, 7 or 8 in adult whorl, increasing rather evenly in size as added, only slightly inflated; sutures distinct, limbate, slightly if at all depressed, strongly curved on dorsal side, nearly radial on ventral side; wall smooth, distinctly perforate; aperture ventral, opening into umbilical area, with distinct, overhanging lip.

Length, 0.48 mm.; breadth, 0.40 mm.; thickness 0.25 mm.

Holotype (Cushman Coll. No. 38601) from the Tumey formation, at a depth of 4069 feet, in Seaboard Oil Co.'s Welch No. 1 well, Fresno Co., Calif.

This species differs from *Valvulineria jacksonensis* Cushman in the more elongate form, and in the more convex, more distinctly umbilicate, and more involute ventral side. It is named in honor of Norman L. Thomas of the Pure Oil Co.

Genus GYROIDINA d'Orbigny, 1826
GYROIDINA CONDONI ROTUNDIFORMIS Cushman and Simonson, n. var.
Plate 33, figures 17–19

Variety differing from typical form in the strongly rounded periphery, more oblique sutures, and more coarsely perforate test.

Holotype of variety (Cushman Coll. 38603) from the Tumey formation, at a depth of 3555 feet, in Seaboard Oil Co.'s Welch No. 1 well, Fresno Co., Calif.

This variety is fairly common in the *Uvigerina cocoaensis* zone.

GYROIDINA cf. G. SOLDANII d'Orbigny
Plate 34, figure 1

A form with acute periphery may be referred questionably to this species. It is common in some parts of the section.

Genus EPONIDES Montfort, 1808
EPONIDES DUPRÉI CIERVOENSIS Cushman and Simonson, n. var.
Plate 34, figures 2, 3

Variety differing from typical form in the much more rounded test and broadly rounded periphery.

Holotype of variety (Cushman Coll. No. 38606) from the Tumey formation, at a depth of 3970 feet, in Seaboard Oil Co.'s Welch No. 1 well, Fresno Co., Calif.

EPONIDES cf. E. UMBONATA (Reuss)
Plate 34, figures 4, 5

Specimens very close to this widely distributed species occur in the well samples. It is recorded from Eocene to Recent.

Genus EPISTOMINA Terquem, 1883
EPISTOMINA EOCENICA Cushman and M. A. Hanna
Plate 34, figure 6

Epistomina eocenica Cushman and M. A. Hanna, 1927, San Diego Soc. Nat. History Trans., vol. 5, no. 4, p. 53, pl. 5, figs. 4, 5.—Cushman and Schenck, 1928, Univ. California Publ., Bull. Dept. Geol. Sci., vol. 17, p. 313, pl. 44, figs. 9a–c.—Weinzierl and Applin, 1929, Jour. Paleontology, vol. 3, p. 407.—Cushman and McMasters, 1936, idem, vol. 10, p. 515, pl. 76, figs. 5a–c.

The records for this species are all from the Eocene or Oligocene.

Family CASSIDULINIDAE
Genus CASSIDULINA d'Orbigny, 1826
CASSIDULINA GLOBOSA Hantken
Plate 34, figure 7

Cassidulina globosa Hantken, 1881, K. ungar. geol. Anstalt Mitt. Jahrb., vol. 4, p. 64, pl. 16, figs. 2a, b.—Liebus, 1901, Neues Jahrb. für Min., 1906, p. 125; Jahrb. Geol. Reichsanst., vol. 56, p. 357, fig. 5.—Cushman, 1925, Cushman Lab. Foram. Research Contr., vol. 1, pt. 3, p. 56, pl. 9, figs. 25, 26.—Cole, 1927, Bulls. Am. Paleontology, vol. 14, no. 51, p. 32.—Cushman, 1927, Jour. Paleontology, vol. 1, p. 167, pl. 26, fig. 13.—Cole, 1928, Bulls. Am. Paleontology, vol. 14, no. 53, p. 216 (16).—Cole and Ponton, 1930, Florida Geol. Survey Bull. 5, p. 44, pl. 7, fig. 7.—Church, 1931, Calif. Div. of Mines, vol. 27, p. 212, pl. C, figs. 4, 5.—Cushman, 1935, U. S. Geol. Survey Prof. Paper 181, p. 49, pl. 20, figs. 12a, b; 1939, Cushman Lab. Foram. Research Contr., vol. 15, p. 73.

Cassidulina rel. *globosa* Israelsky, 1939, Sixth Pacific Sci. Congress, Proc., p. 577, pl. 6, fig. 6.

This species has a wide distribution in the Eocene, with one record from the lower Oligocene.

CASSIDULINA sp.
Plate 34, figure 8

Very rare, poorly preserved specimens of a flattened species occur but not with sufficient details preserved for identification.

Family ANOMALINIDAE
Genus ANOMALINA d'Orbigny, 1826
ANOMALINA cf. A. COALINGENSIS Cushman and G. D. Hanna
Plate 34, figures 9, 10

Specimens from the well samples strongly resemble this species described from the Eocene of California.

Genus PLANULINA d'Orbigny, 1826
PLANULINA HAYDONI Cushman and Schenck
Plate 34, figures 11, 12

Planulina haydoni Cushman and Schenck, 1928, Univ. California Publ., Bull. Dept. Geol. Sci., vol. 17, p. 316, pl. 45, figs. 7a–c.

This very distinctive species, described from the Oligocene, Bassendorf shale, of Oregon, occurs in typical form in the well samples.

PLANULINA sp.
Plate 34, figure 13

The figured specimen represents a much flattened species with numerous chambers. It is very rare in the upper part of the section studied and seems to be undescribed, but sufficient specimens for a complete description are not available.

Genus CIBICIDES Montfort, 1808
CIBICIDES HODGEI Cushman and Schenck
Plate 34, figures 14, 15

Cibicides hodgei Cushman and Schenck, 1928, Univ. California Publ., Bull. Dept. Geol. Sci., vol. 17, p. 315, pl. 45, figs. 3–5.

This is a characteristic species of the Bassendorf shale of Oregon, and our specimens from the well samples agree well with the types. Some of the published figures referred to this species from the Miocene are not typical.

CIBICIDES CUSHMANI Nuttall

Cibicides cushmani Nuttall, 1930, Jour. Paleontology, vol. 4, p. 291, pl. 25, figs. 3, 5, 6.—Bermúdez, 1937, Soc. cubana historia nat. Mem., vol. 11, p. 344.—Cushman and Siegfus, 1939, Cushman Lab. Foram. Research Contr., vol. 15, p. 33, pl. 7, figs. 7a–c.—Cushman, 1939, idem, p. 76, pl. 12, figs. 26a, b.

This species was described from the Eocene, Aragón formation, of Mexico and has been recorded from the Eocene, Kreyenhagen shale, of Garza Creek, California, as well as elsewhere. It occurs in the well samples from the transition zone.

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SOME LARGER FORAMINIFERA FROM THE LOWER CRETACEOUS OF TEXAS

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ABSTRACT—Publications concerned with the larger Foraminifera of the Texas Lower Cretaceous are reviewed on the basis of the study of new material. Two old species are discussed and one new species is described.

THE presence of so-called "larger" Foraminifera in the Lower Cretaceous of Texas has been known at least since 1849, when Carl Ferdinand von Roemer first referred to *Orbitulites texanus*, in his book "Texas." This species was well illustrated three years later in his work, "Die Kreidebildungen von Texas und ihre organischen Einschlüsse." Little attention was paid to this type of fossil in the Texas Cretaceous from that time until 1926 when Mrs. Dorothy Ogden Carsey published her paper "Foraminifera of the Cretaceous of Central Texas" (Bull. 2612, University of Texas Bureau of Economic Geology).

Carsey refigured Roemer's *Orbitulites texanus*, transferring it to d'Orbigny's genus *Orbitolina*, erected in 1850. She also described two new species, *Orbitolina whitneyi* and *Orbitolina walnutensis*. In the same year Mrs. Helen K. Hodson described two new varieties of *Orbitolina texana* (Roemer) and a new species, *Orbitolina thompsoni*, from the Cretaceous of Venezuela. The year 1932 brought significant advances in the knowledge of American Cretaceous "larger" Foraminifera. Professor A. Silvestri, of Milan, Italy, obtained Texas material from Mrs. Helen Jeanne Plummer, and in his paper entitled "Revisione di Orbitoline Nordamericane" announced that Carsey's *Orbitolina walnutensis* is, in reality, a *Dictyoconus*, and in his opinion should be regarded as a variety of *Dictyoconus aegyptiensis* (Chapman). Furthermore he regarded her *Orbitolina whitneyi* as synonymous with Roemer's *Orbitolina texana*, which he re-classified as a variety of *Orbitolina concava* (Lamarck).

The results obtained by Silvestri were also, to a large extent, achieved independently by Dr. T. Wayland Vaughan in the course of examination of a collection of Cretaceous material from Guatemala and Venezuela. He regarded *Orbitolina whitneyi* Carsey as a "large sized variant" of *Orbitolina texana* (Roemer) and concluded that *Orbitolina walnutensis* should probably be removed from the genus *Orbitolina*. He also placed *Orbitolina thompsoni* Hodson and the varieties of *Orbitolina texana*, described by Hodson in 1926, in the synonymy of *Orbitolina texana*, which has long been known to be a very variable species. A paper by J. Pfender, entitled "Les Foraminifères du Valanginien provençal" (Soc. géol.

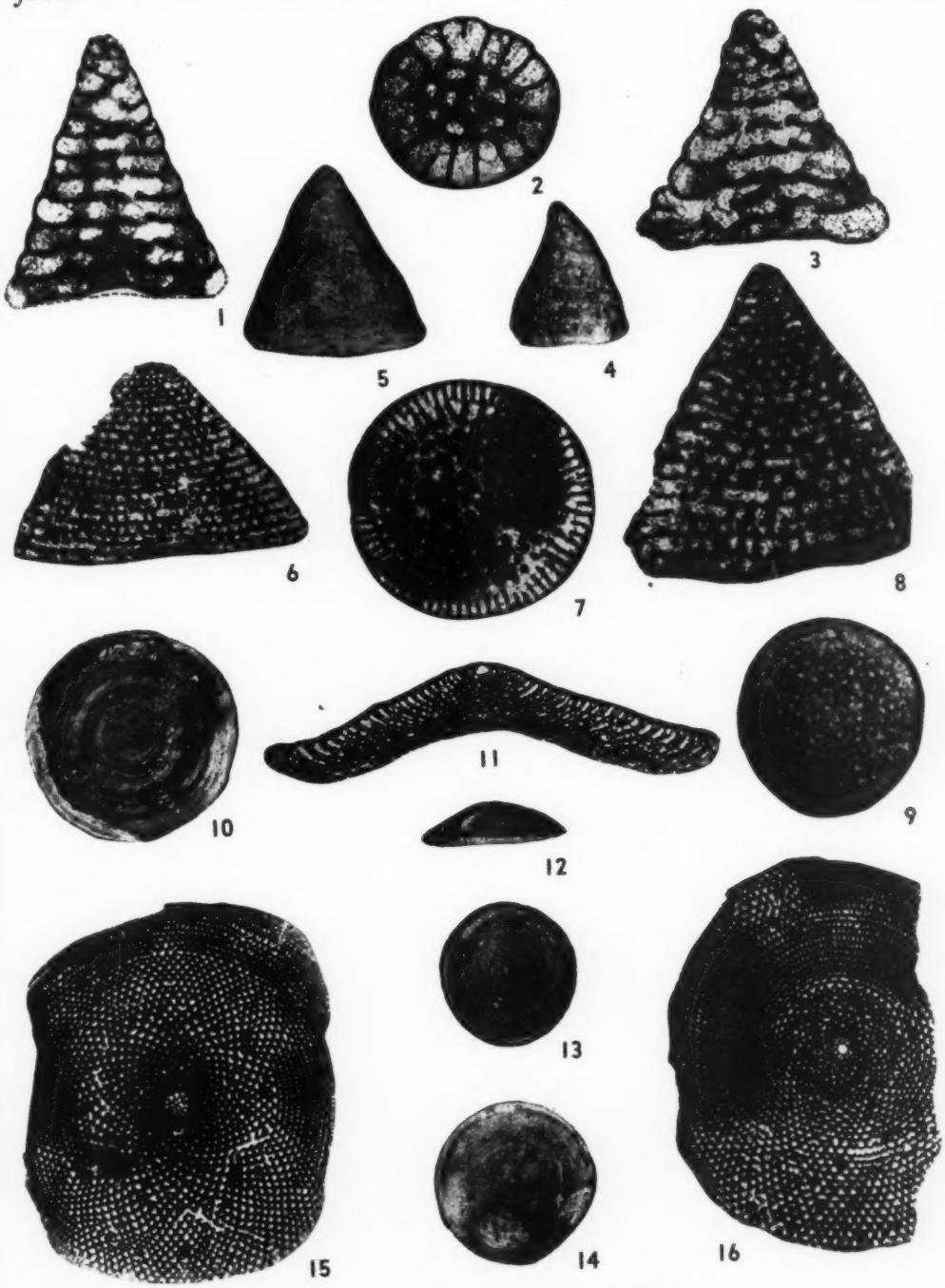
EXPLANATION OF PLATE 35

FIGS. *1–4—Coskinolina adkinsi*, sp. nov. *1*, *3*, Longitudinal section, ×100. *2*, Transverse section ×100. *4*, Exterior, ×50. All specimens from the Walnut Clay, about 4 feet below the base of the Comanche Peak, near the top of Mount Barker, near Austin, Texas. (p. 206)

5–9—Dictyoconus walnutensis (Carsey). *5*, Exterior ×25, side view. *6*, Longitudinal section, ×20. *7*, Transverse section, ×40. *8*, Longitudinal section, ×40. *9*, Exterior view of base of rather larger specimen, ×25. All specimens from lowest strata of Comanche Peak formation, near the top of Mount Barker, near Austin, Texas (topotypes?) (p. 205)

10—"Orbitolina whitneyi" Carsey (topotype?), exterior, ×4 (from near Fischers Store, Blanco—San Marcos Road, Comal County, Texas). (p. 208)

11–16—Orbitolina concava texana (Roemer). *11*, Longitudinal or cross section of typical form, ×20. *12*, *13*, Exterior, typical form, ×4. *14*, Exterior intermediate between typical form and *"Orbitolina whitneyi,"* ×4. *15*, *16*, Median or transverse sections of the typical form, ×20. Glen Rose formation, near Fischers Store (0.3 miles east), on the Blanco-San Marcos Road, Comal County, Texas. (p. 207)



Barker, Cretaceous Foraminifera

UNIV. OF MICH.

France Bull., sér. 5, t. 8, 1938, pp. 231–242, pls. 13–16) recorded the presence of *Dictyoconus walnutensis* (Carsey) at a number of Lower Cretaceous localities in France, Persia and Mexico, in beds ranging in age from Valanginian to Upper Cenomanian. One locality, near Xilitla, in Mexico, has been attributed to the Turonian, thus extending the range of the species even higher in the section. Of especial interest in this paper is the recognition of *Coskinolina* sp. in beds thought to be Cenomanian at a locality near Xilitla, Mexico, and from the Valanginian near Toulon.

The species of *Coskinolina* is, unfortunately, not described, and the sections figured, in massive limestones, leave much to be desired. The species, if truly a *Coskinolina*, which seems probable, constitutes the first Cretaceous record for the genus known to the writer, and is thought to be quite distinct from the new species, *Coskinolina adkinsi*, n. sp., described from the Lower Cretaceous of Texas. Pfender's figures (see his pl. 14, fig. 5; pl. 15, figs. 5–6) indicate a larger form, much less acutely conical and less primitive than *C. adkinsi*. Two figures however (pl. 14, fig. 6; pl. 15, fig. 4) show what may be a second species of *Coskinolina*, which is rather closer to *C. adkinsi*, but with a more complex form of test, with better developed septa.

Dictyoconus walnutensis and *Coskinolina* sp., in the collections examined by M. Pfender, are associated with *Pseudocyclammina lituus* (Yokoyama), *Coscinoconus* sp., and *Eorupteria neocomiensis* n. sp.

Studies of *Orbitolina texana* and *Dictyoconus walnutensis* giving considerable detail were published in 1939 by Lieut.-Colonel L. M. Davies in his paper, "An early *Dictyoconus* and the genus *Orbitolina;* their contemporaneity, structural distinction and respective natural allies" (see literature list). Colonel Davies apparently did not agree with Silvestri that *Orbitolina texana* is a variety of *O. concava* (Lamarck), although this is not specifically mentioned in the text, and he refers to *Orbitolina whitneyi* only as a "companion form to *Orbitolina texana*" with no discussion of their implied synonymy. He also abandoned Silvestri's *Dictyoconus aegyptiensis walnutensis* (Carsey) for *Dictyoconus walnutensis* on account of the smaller size and simpler structure of the Texas form.

In 1940 and 1941 the writer visited several localities in the neighborhood of Austin, Texas, accompanied on different occasions by W. S. Adkins, Mrs. Helen Jeanne Plummer, and Dr. Frank E. Lozo, Jr., to whom thanks are due for very generous assistance in finding localities and obtaining good material. Numerous samples were collected, containing abundant *Orbitolina texana*, also topotype material of *Dictyoconus walnutensis* (from near the top of Mount Barker, near Austin) and of *Orbitolina whitneyi* (from near Fischers Store, San Marcos-Blanco road, Comal County). Thanks are due to Dr. Lozo for material from the Fort Worth area, including samples collected at some of the localities listed by S. A. Lynch in this journal in 1933, from which he recorded *Dictyoconus walnutensis*. During 1941 numerous thin sections were made from this material and many of these were photographed to facilitate comparison. The writer wishes to express his gratitude to Shell Oil Company, Inc., for permission to publish the results of this short study. Thanks are due Mr. Milford Kinsey of Houston for assistance in making several of the microphotographs.

All figured specimens have been presented to the United States National Museum, and duplicate specimens have been deposited at the Bureau of Economic Geology at Austin, Texas.

DESCRIPTION OF SPECIES

Family VALVULINIDAE
Subfamily ATAXOPHRAGMIINAE
Genus DICTYOCONUS
Blanckenhorn, 1900
DICTYOCONUS WALNUTENSIS (Carsey)
Plate 35, figures 5–9

Orbitolina walnutensis Carsey, 1926, Texas Univ. Bull. 2612, p. 23, pl. 7, figs. 11a–b; pl. 8, fig. 3.

Orbitolina walnutensis, Adkins, 1928, Texas Univ. Bull. 2838, p. 62.

Orbitolina? walnutensis, Vaughan, 1932, Nat. Acad. Sci. Washington Proc., vol. 18, no. 10, pp. 609–610.

Dictyoconus aegyptiensis walnutensis, A. Silvestri, 1932, Accad. Nuovi Lincei Mem., ser. 2, vol. 16, pp. 377–381, pl. 1, figs. 10–12; pl. 2, figs. 3–5.

Dictyoconus aegyptiensis walnutensis, A. Silvestri 1932, Palaeontogr. Ital. n. s., vol. 32, p. 159.

Dictyoconus walnutensis, Davies, 1939, Roy. Soc. Edinburgh Trans., vol. 59, pt. 3, no. 29, pp. 775–776, pl. 1, figs. 4, 6.
Probably not *Orbitolina walnutensis*, Lynch, 1933, Jour. Paleontology, vol. 7, no. 1, pp. 110–111.

Topotype material of this species was sectioned and photographed and specimens are figured for comparison with the much smaller *Coskinolina adkinsi*, n. sp. As may be seen from these figures it is a true *Dictyoconus*, although rather more primitive than its Eocene descendants, as noted by Colonel Davies. Sections were carefully compared with specimens and sections of *Dictyoconus aegyptiensis* (Chapman) from British Somaliland, made available through the generosity of Dr. A. G. Brighton of the Sedgwick Museum, Cambridge, England. This comparison confirms the view of Davies, namely that Prof. Silvestri was mistaken in regarding the Texas form as a variety of Chapman's species. The latter is considerably larger, possesses a more complex structure of the marginal trough, and moreover is an Eocene form which has never been reported from the New World. *D. walnutensis* is therefore regarded as a valid species, and the earliest known member of the genus.

This species was thought to occur typically in the Walnut clay of Texas, but detailed work at the type locality and elsewhere by Mrs. Plummer and Dr. Lozo has revealed the fact that it occurs abundantly in the lower part of the overlying Comanche Peak limestone but, where fresh material was obtained by trenching, no specimens of *Dictyoconus* were found in the underlying Walnut clay. The belief that it occurred abundantly in the Walnut clay very probably is due to the fact that abundant well-preserved specimens weather out from the basal Comanche Peak and congregate in slumped surface material. Great care is required when collecting to avoid contaminating the Walnut clay samples with this slumped material from the overlying Comanche Peak formation.

Walnut clay samples collected near Austin and samples collected from the Goodland limestone in the Fort Worth area by Dr. Lozo contained no *Dictyoconus walnutensis* but large numbers of a much smaller conical form were found. Although this form superficially resembles *Dictyoconus*, thin sections show it to possess a more primitive structure than *D. walnutensis*, and a study of the literature shows it to be a *Coskinolina*. It is highly probable that this form was confused with *Dictyoconus walnutensis* by Lynch, who has recorded "*Orbitolina walnutensis*" from numerous localities in the Fort Worth region, where sampling by Lozo show no *Dictyoconus* but fairly abundant *Coskinolina*.

Occurrence: So far as can be ascertained *Dictyoconus walnutensis* (Carsey) occurs only in the Comanche Peak of the Austin region. It has not yet been found in samples from farther northeast (Fort Worth, etc.).

Genus COSKINOLINA Stache, 1875
COSKINOLINA ADKINSI Barker, n. sp.
Plate 35, figures 1–4

Test small, conical, generally about as high as broad; outer wall straight or slightly concave, meets base in fairly sharp sometimes protruding angle. Base flat to slightly concave, central portion ("central shield") marked by numerous circular perforations (apertures?). Externally test (usually more or less weathered), marked by corrugations representing successive cups of which it is composed; in some specimens corrugations show the subdivisions formed by vertical partitions in marginal trough. Corrugations seen in thin sections to be about 0.045 mm. in height. Twenty specimens have the following dimensions:

Height (mm.)	Base Diam. (mm.)
0.45	0.40
0.40	0.43
0.45	0.35
0.40	0.45
0.40	0.35
0.45	0.35
0.35	0.35
0.35	0.40
0.35	0.40
0.45	0.40
0.40	0.45
0.35	0.325
0.40	0.40
0.30	0.325
0.35	0.35
0.40	0.40
0.35	0.35
0.35	0.45
0.40	0.40
0.40	0.45

These figures show the range in size of the species, and its variations in shape, from a squat cone through one showing equal base and height to a much more acute form. The average calculated from the above figures gives an equal height and basal diameter of 0.39 mm., which compares with a height of 1.6 mm. and base diameter of 1.5 to 1.6 mm., average measurements for *Dictyoconus walnutensis*. The apex is subacute; the wall appears to be finely arenaceous but no analyses were made, and Col. Davies (1930) describes the test of *Lituonella*, *Coskinolina*, and *Dictyoconus* as "porcellanous."

Sections show the test to consist of an initial trochiform spire (very short and not well shown in the figures) which is followed by a series of chambers or "cups" arranged uniserially and rapidly increasing in diameter as added. The peripheral portion of each cup shows a marginal trough, which, in transverse or cross sections perpendicular to the axis of the cone, is subdivided into simple chamberlets by radial partitions extending inwards from the periphery. This marginal trough, or furrow, is clearly marked, measuring from 0.045 mm. to 0.05 mm. in height, the successive cups or chambers in the central portion of the test measuring only 0.03 mm. in height (average measurement on 5 sections). Pillars are not well developed in any of the sections made, and in most can best be described as rudimentary to absent; they are, perhaps, better regarded as "buttresses, kidney-shaped or semilunar in cross section near their base," as described by Davies. No definite evidence of dimorphism was obtained from the sections examined, nor from the inspection of a large suite of specimens, although it is possible that the more elongate specimens, with more acute apices (somewhat damaged in all specimens examined) may perhaps represent the microspheric form.

The central shield shows a number of circular perforations measuring 0.0125 mm. to 0.02 mm. in diameter, their centres being approximately 0.04 mm. apart; in some sections a slight upturning of the floor of the cup at the edge of the perforations (seen in sections parallel to the axis of the cone) represents the rudimentary pillars mentioned above. The marginal trough is about 0.08 mm. in width, and the chamberlets into which it is subdivided show an average dimension of 0.08 mm. by 0.05 mm. in sections measured.

This species possesses the typical structure of *Coskinolina* as demonstrated by Davies (1930) but differs from all species previously described in its much smaller size and more primitive character. So far as known it is the oldest recorded and only Cretaceous species of *Coskinolina* and its presence in the Walnut clay, immediately underlying the Comanche Peak limestone beds which contain the earliest known *Dictyoconus*, supplies additional evidence for the derivation of *Dictyoconus* from *Coskinolina*, as postulated by Schubert, Douvillé, Cushman, and Galloway. Since the earliest known *Lituonella* occurs in the Lower Eocene, it cannot be regarded as the ancestor of *Coskinolina*, but more probably, as suggested by Davies (1939) developed from that genus by a process of simplification or degeneration.

Occurrence: The range of the species is not fully known. It occurs typically in the Walnut clay at several localities near Austin and has been found in the Goodland limestone near Fort Worth.

Types: Holotypes and paratypes selected from clays of Walnut (Lower Cretaceous) age, approximately 4 feet below the base of the Comanche Peak, near the top of Mount Barker, near Austin, Texas. Types deposited in the United States National Museum.

Family ORBITOLINIDAE Martin, 1890

Genus ORBITOLINA d'Orbigny, 1850

ORBITOLINA CONCAVA TEXANA (Roemer)

Plate 35, figures 10–16

Orbitulites texanus Roemer, 1849, Texas, Bonn, p. 392.

Orbitulites texanus, Roemer, 1852, Kreidebildungen von Texas, etc., p. 86, pl. 10, figs. 7a–d.

Orbitulites lenticularis, Karsten, 1856, Amtlicher Ber., 32 Vers. deutsche Nat. Aerste, Wien, p. 114, pl. 6, 6a–e.

Orbitulina venezuelana Karsten, 1886, "Géol. Colomb. bolivar." etc., p. 62, pl. 6, figs. 6a–e; Cretaceous, Venezuela.

Patellina texana, Hill, 1893, Biol. Soc. Washington Proc., vol. 8, p. 20, pl. 1, figs. 2 (after Roemer), 2a–d; Glen Rose formation of central Texas.

Orbitulina lenticularis (*?concava* Lamarck) Ger-

hardt, 1897, Neues Jahrb., Bd. XI, p. 194; (Upper Cretaceous, near Bogotá, Colombia.)
Orbitolina whitneyi Carsey, 1926, Texas Univ. Bull. 2612, p. 22, pl. 6, fig. 9; Lower Cretaceous, Texas.
Orbitolina texana, Carsey, 1926, idem, p. 22, pl. 6, figs. 6a–c; Lower Cretaceous, Texas.
Orbitolina texana, Hodson, 1926, Bulls. Am. Paleontology, vol. 12, no. 47, p. 5, pl. 1, fig. 2; Cretaceous, Venezuela.
Orbitolina texana asaguana Hodson, 1926, idem, p. 5, pl. 1, figs. 6, 8; Cretaceous, Venezuela.
Orbitolina texana monagasana Hudson, 1926, idem, p. 5, pl. 1, figs. 7, 9; Cretaceous, Venezuela.
Orbitolina thompsoni Hodson, 1926, idem, p. 5, pl. 1, figs. 1, 5. Cretaceous, Venezuela.
Orbitolina texana, Silvestri, 1932, Palaeont. Italia, n. s., vol. 32, p. 174.
Orbitolina whitneyi, Silvestri, 1932, idem, vol. 32, p. 174.
Orbitolina concava texana, Silvestri, 1932, Mem. Accad. Nuovi Lincei, ser. 2, vol. 16, pp. 372–376, pl. 1, figs. 1–9; pl. 2, figs. 1–2; Cretaceous, Texas.
Orbitolina texana, Vaughan, 1932, Nat. Acad. Sci. Washington Proc., vol. 18, no. 10, pp. 609–610; Cretaceous, Guatemala and Venezuela.
Orbitolina texana, Muir, 1936, Geology of the Tampico Region, Mexico, pp. 20, 21, 40, 96, 222, pl. 2, fig. D; Cretaceous, Mexico.
Orbitolina concava texana, Hedberg, 1937, Geol. Soc. America Bull., vol. 48, pp. 1986–1987, pl. 4, figs. 1–2; Cretaceous, eastern Venezuela.
Orbitolina texana, Davies, 1939, Roy. Soc. Edinburgh Trans., vol. 59, pt. 3, no. 29, pp. 783–784, pl. 1, figs. 1, 3, 7, 9, 12; Cretaceous, Texas.
Orbitolina sp. (*?texana* (Roemer)), Vaughan and Cole, 1941, Geol. Soc. America Spec. Papers 30, p. 31, pl. 8, figs. 2–4; Lower or Middle Cretaceous, Trinidad, B. W. I.

This species is one of the most characteristic fossils at many horizons in the Glen Rose formation in the neighborhood of Austin, Texas, where it shows considerable variability. Specimens from the Fort Worth area, collected by Dr. Lozo, are not figured, but are similar to those from near Austin, though smaller, rather more conical, with a more convex base in which the central depression is less accentuated than in the typical form. The species appears to be rare and generally poorly preserved in the eastern and northeastern parts of Texas but is clearly identical with the species collected around Austin.

Orbitolina whitneyi was described by Carsey from material collected "near Fischers Store," which is on the Blanco-San Marcos road, near Austin. Large quantities of material were collected about 1.0 miles west of Fischers Store and 0.3 miles east of it in 1939–40, and suites showing the range of variation were picked from these samples. A number of very depressed specimens were found which measured from 7.0 mm. to 9.00 mm. in diameter, which agree closely with the figure of *O. whitneyi*. Carsey gives the diameter as "up to 14.00 mm." but figures as her type a specimen only 10.00 mm. in diameter. The largest specimens collected in 1939–1940 were fragmentary, but did not exceed 10–11 mm.

Careful comparison of these topotypes of *O. whitneyi* with suites of *O. texana* revealed no differences other than the flatter and larger test of the former, and even this is regarded as strictly gradational. Sections show no apparent structural differences greater than the variation shown in a series of sections of *O. texana*. *Orbitolina texana*, as is well known, is very variable in form and size, and it does not appear to be justifiable to separate *O. whitneyi* even as a subspecies, a conclusion already reached by Silvestri and by Vaughan, although the latter classed it as a "large sized variant" (not "variety") of *O. texana*.

Forms comparable to Carsey's *O. whitneyi* seem to be extremely rare, and where present they are accompanied by a great abundance of typical *O. texana*. It is conceivable that the former are the microspheric generation of the latter. All sections of "*Orbitolina texana*" showing the embryonic apparatus have proved to be megalospheric, and no sections showing the embryonic apparatus of the much rarer "*O. whitneyi*" have been obtained, and therefore the microspheric nature of the latter can not be demonstrated. This hypothesis, however, accords with the larger test and greater rarity of "*O. whitneyi*," and with what has long been known concerning the dimorphous forms of many species of the Orbitoididae, as well as other groups. So far as the writer is aware, however, nothing has as yet been noted regarding the possible dimorphism of *Orbitolina*, and the form it takes in this genus.

Orbitolina texana seems to be almost identical with the European *O. concava* (Lamarck) (described as *Orbitolites* in 1801), as revealed by a study of available figures and descriptions, but, in the absence of comparative material, it would be rash to regard

them as synonymous. Silvestri had abundant material of both species and decided that *O. texana* should be classed as a variety of *O. concava*, a conclusion which, coming from such a careful worker, would appear to be final. However, since typical *O. concava* has not been reported from the Americas and *O. texana* is not known from the Old World it would seem preferable to regard the Texas form as a geographic variant or subspecies of *O. concava* rather than as a true variety (occurring with the type).

Occurrence: *Orbitolina concava texana* (Roemer) occurs abundantly in the Glen Rose limestone of Texas in the neighborhood of Austin and elsewhere. Mrs. Plummer (1932, Univ. Texas Bull. 3232, p. 334) has recorded it as rare in the Walnut clay, near the top of Mount Barker, near Austin, and specimens collected from this locality by the writer in 1940 appear to be identical specifically with specimens from the Glen Rose, although smaller than average size. Udden has reported the species from the Presidio formation in the Shafter section, which may be Travis Peak in age, and Dr. Cuyler notes that it occurs abundantly in the upper Hensell sands of the upper Travis Peak (1939, p. 637). As has been noted, it occurs abundantly at many localities in southern Texas and more rarely in the eastern and northeastern parts of the State. It has been recorded from Mexico by John M. Muir, from Guatemala by T. Wayland, Vaughan, from Colombia by Gerhardt and Karsten (as *Orbitulina lenticularis ?concava*), and from Venezuela by Karsten, Hodson, Vaughan, and Hedberg. It probably occurs also in Trinidad, as a closely similar form has recently been figured from there by Vaughan and Cole. It thus has a wide range in the Caribbean region, where it probably indicates beds of Aptian age.

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MACHINE FOR SERIAL SECTIONING OF FOSSILS

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ABSTRACT—A machine is described which was designed to grind parallel sections of fossils at exact intervals of 0.5 millimeter or more. Its chief advantages over previously used devices are its speed of operation and its accuracy. A cup-shaped grinding wheel is used instead of a flat-faced wheel; little frictional heat is developed in the cutting process, and the use of water is not necessary.

A summary is given of the steps used by the authors in preparing serial sections of Oligocene mammal skulls and in permanently recording them by the nitrocellulose peel method.

INTRODUCTION

IN THE course of studies of the endocranial anatomy of fossil Artiodactyla, the authors employed serial sectioning technique, as used by many workers in the investigation of the internal morphology of fossils, both vertebrate and invertebrate. Among researches carried on by this means are those of Bulman (1925) on graptolites; Stainbrook (1942) and many other workers on brachiopods; Sollas (1903) on the technique as applied to vertebrates in general; Stensio (1926, 1927) on the Agnatha; Romer (1937) and Dunkle (1940) on the Osteichthyes; Sollas (1920) and Sawin (1941) on the Amphibia; Sollas (1914, 1916) on the Reptilia; and Simpson (1936) on the Mammalia.

The serial sectioning method involves exposure of the interior of the specimen by careful grinding upon an abrasive surface; after study of the first section, the operation is repeated in such a way that each succeeding section is parallel to the first. The specimen should be ground down the same distance at each operation; in this way, any structures observed can be properly oriented in relation to the specimen as a whole.

While using this method, several technical difficulties were encountered, to obviate which, the machine to be described below was constructed.

The usual apparatus used in grinding serial sections is a horizontal steel lapidary's wheel, on which a thin stream of water is played. Fine abrasive powder (carborundum or emery), sprinkled upon the wheel as it revolves, forms a sludge which performs the grinding.

This means of grinding presents several disadvantages. If the specimen (and consequently the section interval) is large, considerable time is consumed in grinding. As a result of the unequal hardness of bone, matrix, and of the plaster in which the specimen is usually embedded, it is difficult to achieve a plane surface if the specimen is simply held in the hand; and such a surface is necessary if the operation is to yield a series of parallel sections. G. G. Simpson (1933) has devised a holding mechanism which obviates this difficulty for small specimens, but it is not adaptable for large ones. Another difficulty lies in the fact that the use of water in grinding necessitates a long period of drying before the parlodion peel method (see below) can be used to obtain a permanent record of the section. Finally, no method has previously been devised whereby large specimens can be accurately ground at intervals as small as 0.5 mm., which was necessary for the work being undertaken by the authors.

An attempt was, therefore, made to perfect a device which would allow quick grinding, without the use of water, of parallel serial sections. The machine which was built for this purpose is shown in the accompanying figure.

THE SERIAL SECTIONING MACHINE

Like its prototype of industrial dimensions, the horizontal surface grinder described in this paper consists essentially of

three parts: (1) a rigidly braced bed, (2) a headstock which supports the spindle, and (3) a work table capable of travel in both longitudinal and the transverse directions. Certain modifications have been introduced with a view toward specially adapting this machine for the work in hand, as, for example, the metric feed screw which furnishes longitudinal motion to the carriage. To facilitate construction, no iron castings have been used; machining has been held to a minimum; and at certain points standard practice has been abandoned in favor of procedures more practicable in the small shop of limited equipment. It is suggested, moreover, that the individual technician may well depart from these specifications wherever by so doing he can build a machine from more readily available materials without, of course, impairing its efficiency.

The bed is made up of two iron channels each 1½ by 4 inches, and 18 inches in length. These are spaced 2½ inches apart and rigidly held in position at 5 points by a sleeve and bolt assembly as shown in *D*. Machine bolts 4½ by 5/16 inches are used. The sleeves are cut from 1-inch diameter steel shafting and are suitably drilled to receive the bolts. Sleeves should be carefully faced at each end to insure accurate spacing of the channels. A sixth brace is provided by the angle iron (*A*), which also supports the outer ends of the carriage ways parallel to the bed. This angle iron is best secured to the bed by bolts entering holes previously drilled and tapped in the upper flange of each channel.

The headstock consists of four angle irons, each double-bolted to the inner surface of the bed channels. One pair of angles supports the inboard spindle bearing; the second pair, the outboard bearing. Fastened across the two front uprights (*A*) is a hardwood panel upon which is mounted a 10 ampere switch in circuit with the motor.

While the choice of spindle bearings rests with the individual technician, it is suggested that plain sleeve bearings either of bronze or of babbit can be more easily and cheaply installed than any other kind, especially by the novice. One entirely feasible scheme is to employ ordinary pillow blocks on cross bars attached to the uprights which form the headstock. In the present case, babbit was used in steel retainers, each retainer having a flange by means of which it could be screwed to the headstock at four points (*B*). The greatest care must be exercised in locating and drilling the necessary holes for this assembly; otherwise, the spindle will bind. After the babbit has been poured, each bearing should be bored to an exact ¾-inch size in the lathe. Finally, an oil hole should be drilled in both. Care must be taken to see that these retainers are suitably formed on their inner surfaces to prevent turning or displacement of the babbit. This difficulty is of course obviated when bronze sleeves are employed, for in the latter case the bearing is force-fitted to its retainer.

The spindle itself is a 10-inch length of ¾-inch diameter machinery steel, turned down at the inboard end to ½ inch. The nose is threaded right hand ½–24 and provided with a shoulder. The latter is a separate piece pressed on the spindle and subsequently machined to run true, especial care being taken with the face. Both this operation and that of threading the spindle nose must be performed between centers on the lathe. A properly selected cup wheel with ½-inch center hole is mounted on the spindle nose and held tight against the shoulder by a large concave washer and nut. A 5-inch carborundum wheel with a rim height of two inches was well suited to the authors' purposes (see *A*). Such a wheel as this permits rapid dry grinding with almost no development of heat due to friction. Dry grinding of fossil material is impossible with a flat abrasive wheel. When mounting the wheel the operator should also use the thick paper washers ordinarily supplied for that purpose by the manufacturer. One of these is placed on either side of the wheel. In order to provide a range of speeds a 4-step V pulley cone is mounted on the spindle between bearings. This is matched by a similar cone on the shaft of the motor, the latter being most conveniently placed directly behind the headstock of the machine. End play of the spindle is restricted by a collar as shown in *F*.

The carriage (*C*) consists of a rectangular steel plate beneath which are secured the four pillow blocks that serve as bearings for this entire assembly. Interposed between

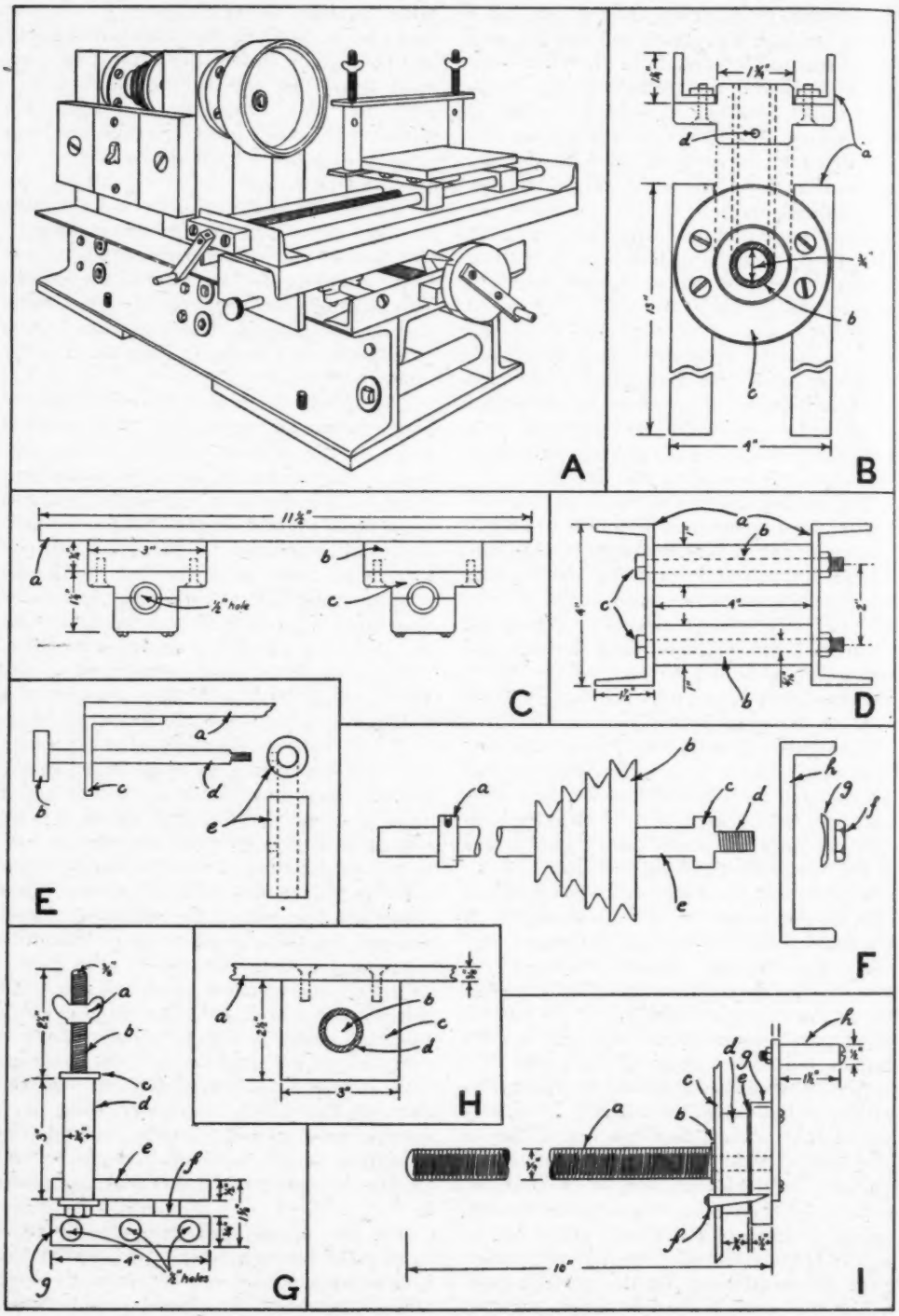

FIG. 1

each pillow block and the carriage plate is a spacer. By this device not only is the mounting of the feed nut facilitated, but provision is made for adjusting the height of the work table with respect to the spindle—a helpful feature in certain classes of work.

Movement of the carriage is along polished steel rails (½-inch round) rigidly supported above and parallel to the bed proper. These rails are precisely center-drilled and tapped ¼–20 at each end. The manner of support is illustrated in *A*. The movement itself is accomplished manually through a feed screw and bronze nut mechanism. A pitch of 2.5 mm. is employed for the screw, since this metric thread can be readily cut on most small bench lathes without the use of special accessories. Here again the operation should be performed between centers, in the present case on a suitable length of ¾-inch steel shafting.

Fastened to the outboard end of the feed screw, which is turned down for the purpose, is a 2½-inch diameter steel disc or index head, the peripheral face of which is marked off into five segments. Thus, given the above pitch of 2.5 mm., it will be seen that a turn of the screw through 72° causes the carriage to move 0.5 mm. Position of the index head is determined relative to a fixed pointer as shown in *I*. The addition of a handle permits use of the index head as a crank.

The bronze nut, turned from a short length of 1¼-inch diameter stock so as to exhibit a flange, is force-fitted to a small rectangular steel plate mounted perpendicularly for that purpose beneath the carriage plate and exactly in the center (see *H*). Great care must be taken in locating both the nut and the outer bearing of the feed screw, otherwise binding will result.

Since for accurate work the carriage must remain absolutely fixed while a cut is being made, an efficient lock mechanism is provided as shown in *E*. This consists of a steel or brass cylinder bored throughout its length to a sliding fit on the carriage way and of such length as to sit snugly between one pair of pillow blocks. At midlength the wall of this cylinder is drilled and tapped to receive the threaded end of a brass rod, the outer end of which, passing for support through a piece of angle iron bolted beneath the carriage plate, is provided with a knurled head. A slight turn of the latter is sufficient to lock the carriage.

The cross slide or work table, essentially a duplication of the carriage, serves to carry the work across the face of the cup wheel at right angles to the bed. It consists of a steel plate, 4 by 5 inches, to the lower surface of which are attached bearings and a second bronze nut. Traverse is accomplished manually by means of another feed screw and nut mechanism, the table sliding along a second set of polished steel rails supported on the upper surface of the carriage. In this case no advantage derives from the employment of a metric thread, although it is suggested that a fine pitch will be found preferable to a coarse, the former helping to insure a smooth finish on the work. As before, the outer end of the screw is turned down to receive a crank.

The device for clamping work to the

EXPLANATION OF FIGURE 1

FIG. *A*—Horizontal surface grinder.
B—Headstock. *a*. angle irons; *b*. babbit; *c*. flange of retainer; *d*. oil hole.
C—Carriage assembly (side elevation) *a*. carriage plate ($11\frac{1}{2}'' \times 5'' \times \frac{3}{8}''$); *b*. spacer block ($\frac{3}{4}'' \times \frac{3}{4}'' \times 3''$); *c*. pillow block.
D—Bed assembly (end view) *a*. channels ($4'' \times 1\frac{1}{2}''$); *b*. spacers ($4'' \times 1''$ round; $\frac{5}{16}''$ hole); *c*. machine bolts ($4\frac{1}{2}'' \times \frac{5}{16}''$).
E—Carriage lock mechanism (side elevation) *a*. carriage plate; *b*. knurled head; *c*. supporting angle; *d*. brass rod; *e*. steel cylinder.
F—Spindle assembly; *a*. collar; *b*. pulley cone; *c*. shoulder; *d*. threaded nose; *e*. spindle; *f*. cup wheel; *g*. concave washer; *h*. nut.
G—Cross slide; *a*. wing nut; *b*. threaded portion of upright; *c*. flat iron; *d*. upright; *e*. work table ($4'' \times 5''$); *f*. spacer; *g*. bearing block.
H—Bronze nut assembly for carriage; *a*. carriage plate; *b*. $\frac{3}{4}''$ opening for metric screw; *c*. nut retainer; *d*. bronze nut.
I—Metric screw; *a*. screw; *b*. washer; *c*. angle iron; *d*. supporting block; *e*. washer; *f*. pointer; *g*. index head; *h*. crank handle.

table is as follows: two 4-inch lengths of ¾-inch shafting are bolted upright at the inboard corners of the worktable. The upper extent of each is turned down to ⅜-inch and threaded. Once the work is in position on the table, a stout iron strap with a hole at each end for insertion of the threaded uprights is placed above the work and forced downward by the action of wing nuts (see *G*).

Operation of the machine should be attended with all customary precautions. Goggles must be worn; spindle speed should at no time exceed manufacturer's rating for the particular wheel in use. If possible, though not here described, some kind of guard should be provided for the wheel. Light cuts are preferable to heavy, and best finish will invariably be achieved by a slow steady traverse of the cross slide.

SECTIONING FOSSIL SKULLS

The methods described here were used in sectioning mammal skulls from the White River (Oligocene) beds, embedded in a matrix of fine calcareous siltstone. The study of specimens from other horizons and other matrices would, of course, necessitate changes in some parts of the procedure.

In order to protect the specimen and orient it permanently for grinding, it is embedded in a block of some sort, usually of plaster. For the authors' current research, ordinary plaster of Paris was used, and the block was hardened by induration with vinyl acetate, a synthetic resin. Even after induration, this plaster was not as hard as might be desired. A more satisfactory block could be made from dental plaster or from "rock plaster" such as is sold under the trade name "Hydrocal."

In early serial sectioning studies, each successive section was recorded by camera lucida drawings or by photographs. Another way of obtaining a permanent record is the nitrocellulose peel method, developed by Walton (1928) and Koopmans for use in studying the fossil flora found in coal balls. This method was adapted to other paleobotanic materials by Graham (1933) and was first used in the study of fossil vertebrates by A. S. Romer.

To record a ground section in this manner, a solution of nitrocellulose is poured upon the ground surface, which has previously been etched with acid. After standing for some hours, it forms a film which can be peeled off, preserving a negative caused by the opacity of the matrix clinging to the peel and the translucency of that part of the peel which overlay the bone.

Peeling solutions of various compositions have been advocated by various investigators; in the work here described the nitrocellulose solution advocated by Darrah (1936) was used. Its composition is as follows:

Parlodion Mallinckrodt (a non-explosive commercial cellulose)	80 g.
Butyl acetate	800 cc.
Castor oil	6 cc.
Xylol	60 cc.

In many cases, it has been found necessary to stain the peels before study. In making peels from fossils of the White River series it developed that the matrix, being highly calcareous and loosely cemented, adhered readily and outlined the bones so well that staining was unnecessary.

In summary, the complete method used in obtaining peels of White River mammal skulls was as follows:

1. Skull embedded in block of dental plaster or ordinary plaster of Paris impregnated with vinyl acetate.
2. Block ground down desired distance (in this study the interval varied from 0.5 to 2 mm., according to the size of the skull and the complexity of the region being ground).
3. Ground surface etched lightly with 10% HCl.
4. Ground surface washed carefully with light stream of water.
5. Block dried in oven at low heat for one-half to one hour.
6. Block allowed to cool for one-half hour. If this is not done, air bubbles released during cooling will spoil the nitrocellulose peel.
7. Darrah's peel solution (see above) poured on surface of block. Bubbles broken with a needle.
8. Block allowed to stand for eight hours, then peeled with the aid of a scalpel. The peels should be numbered immediately with India ink.
9. The peels will remain flat permanently

if they are pressed for several days between two heavy pieces of plate glass with weights upon the upper one. No harm will result, however, if they are removed for study during this time.

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JOURNAL OF PALEONTOLOGY, VOL. 18, NO. 2, PP. 216–219, 1 TEXT FIG. MARCH 1944

PALEONTOLOGICAL NOTES

CONODONTS

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The zoological relationships of the conodonts have long been a matter of speculation. Through most of the literature pertaining to their origin and use, the conodonts have been considered as teeth, dermal plates, or other ingestive aides. However, Hass (1941, p. 81) after a study of the internal structure concluded that conodonts were not mouth structures but rather "functioned as the internal supports for tissues located at a place exposed to stress upon the exterior of or within the bodies of some genetically related group of marine animals." The conodonts, however, do not appear to be internal organs, but rather organs used for grasping or holding.

Several papers have presented conodont assemblages, showing that various types of conodonts doubtless existed together in this elusive little animal. This concept, whose foremost advocate is Scott (1934 and 1942), is fundamental in any approach to the zoological relationships of the conodont-bearing animal.

This all leads to the question where in the animal kingdom are there organisms which have various types of chitinous structures not related to the mouth, yet possibly used for holding purposes? During the school year of 1934–35 while engaged in graduate study at the University of Oklahoma, I noticed that among the living worms, including the Nematoda and several groups of the Turbellaria, are organisms whose only chitinous structures are found associated with the reproductive organs, usually of the male. These structures (figs. 1 a –l)are normally kept within the body of the worm but are extruded during copulation and act as an aid to the process. The copulatory structures are paired, single-spined spicules in the Nematoda, become quite complex in some of the flatworms and within the genus *Dalyellia* are the basis of specific differentiation. Here then among the living animals are chitinous structures varying from single spines to stalks set with numerous spines; occurring singly, paired, or in groups within one individual; periodically used for holding, at which times various parts might get broken; harbored internally where the structures could grow, not only from the pulp cavity but also through accretion, and where any broken parts could be healed over in similar fashion. Furthermore these worms have no other hard parts which would have been preserved along with the copulatory structures.

Is the answer to the zoological relationship of conodonts found in the copulatory

EXPLANATION OF FIGURE 1

FIGS. *a*—Structure of Rhabdocoel, *Dalyellia rossi; ch*, chitinous part of male copulatory organ; *mgc*, male genital canal. ×50 (After von Graff).

b–j—Chitinous copulatory structures of various species of *Dalyellia* (After von Graff). *b*, *D. sillimani*, ×330. *c*, *d*, *D. fairchildi*, *c*, ×430; *d*, ×850. *e–g*, *D. articulata; e*, posterior end showing sex organs; *ch*, chitinous part of male organ; *f*, chitinous organ with reduced stalk (*st*); *g*, chitinous portion or cirrus showing variation from *f*, much enlarged, *h*, *D. mohicana*, much enlarged. *i*, *D. viridis*, much enlarged. *j*, *D. rossi*, ×285; *st*, lateral branch with spines; *mv*, and *md*, median ventral and dorsal projection; *q*, transverse bar; *qd*, transverse bar with spines; *st*, stalk.

k–l—Structure of a nematode, *Rhabditis*, mature male; *csp*, copulatory spicule (after Borradaile and Potts).

m—Various forms of nematode spicula (after Cobb).

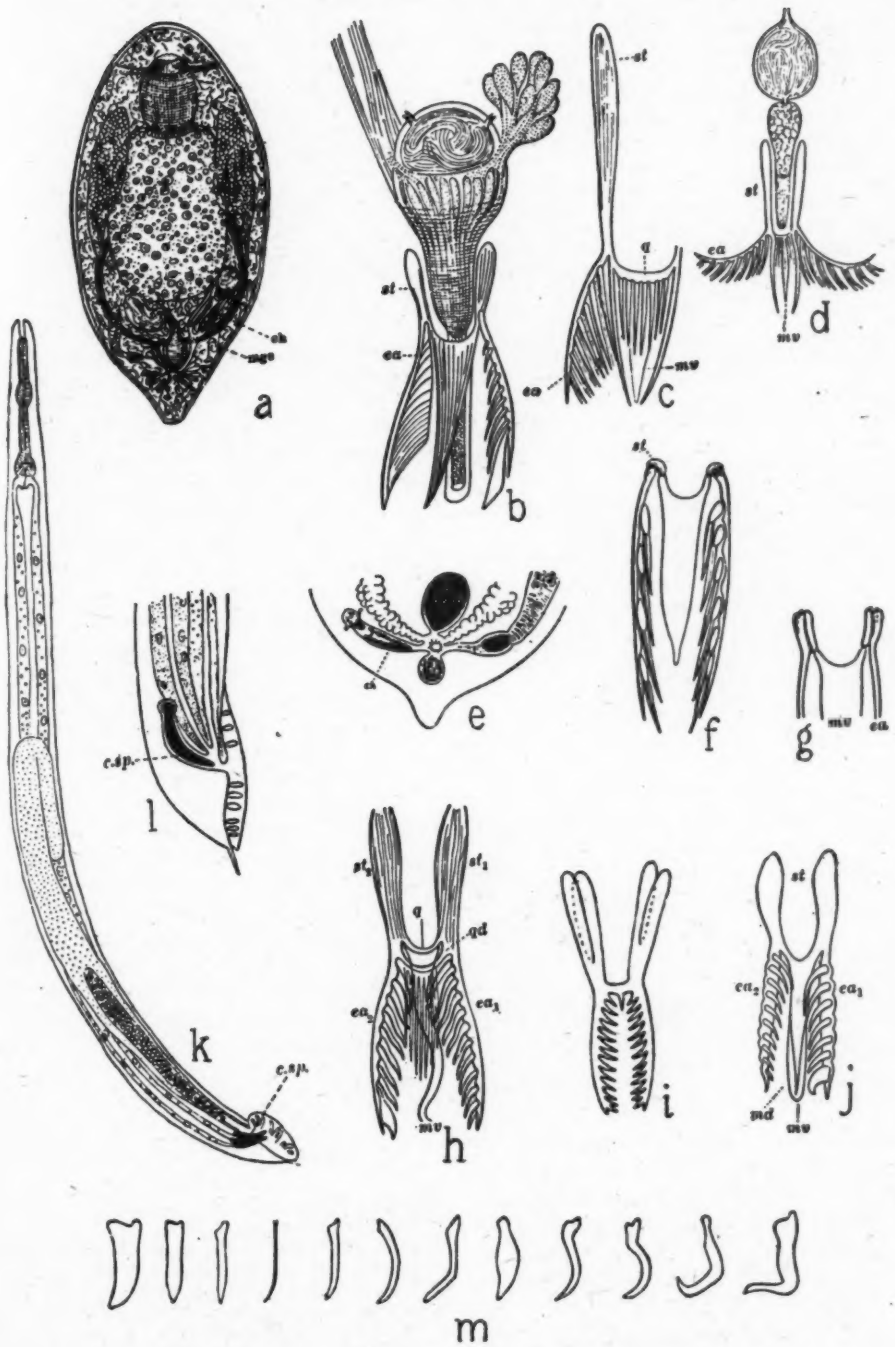

FIG. 1

structures of one or more groups of the worms which finally became extinct through over-specialization?

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UPPER CRETACEOUS FORAMINIFERA FROM NORTHWESTERN PERU: CORRECTIONS

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Seattle, Washington

Unavoidable circumstances prevented me from reading proof on my paper "Upper Cretaceous Foraminifera from Northwestern Peru" (this JOURNAL, vol. 17, no. 4, pp. 331–353, July, 1943). The following corrections should be made:

p. 333 Right column, line 16: for "which others" read "with others"

p. 336 Left column, line 39: for "White (1927" read "White (1928"

p. 339 Left column, line 39: for "Dimensions of holotype" read "Dimensions of paratype"

p. 342 Right column, line 9, line 14: p. 343—left column, line 10, explanation of plate 56, fig. 4: for "*Marginulina texensis*" read "*Marginulina texasensis*"

p. 342 Right column, line 11: for "*Marginulina texensis*" read "*Marginulina texana*"; line 14: for "1928" read "1938"—explanation of plate 55, fig. 12: for "views of holotype" read "views of paratype"

p. 347 Left column, line 25: for "commonest species" read "component species"

p. 350 Left column, line 27: for "species has been established" read "species has not been established"

p. 351 Left column, line 8: for "*Rotalina nitida* (Reuss)" read "*Rotalina nitida* Reuss"

ADDENDA AND ERRATA TO BIBLIOGRAPHY OF PALEOZOIC OSTRACODES

ALLEN F. AGNEW

The following addenda and errata to Paleozoic ostracode references previous to 1942[1] were furnished by the following persons, to whom I am greatly indebted for this information: Chalmer L. Cooper, Carl C. Branson, Mrs. Betty Kellett Nadeau, G. Marshall Kay, and H. N. Coryell.

[1] Agnew, Allen F., *1942*, Bibliographic index of new genera and families of Paleozoic Ostracoda since 1934: Jour. Paleontology, vol. 16, pp. 756–763.

ADDENDA

NEW GENERA

Alvenus Hamilton, 1942, p. 717—*A. depressus* Hamilton, Permian. Cytherellidae.

Cornia, probably described by Lutkevitch in a number of the 73d volume of Monographs of the Paleontology of U.S.S.R. in 1933. (Mentioned in Lutkevitch, 1937, p. 68, and also 1939, p. 193). Permian.

Eocytherella Bonnema, 1933, pp. 150–156. Suggested as a synonym of *Cavellina* (Swartz 1936, p. 583).

Entoprimitia Kummerow, 1939, p. 19—*E.*

hattingensis (Matern). Devonian to Mississippian. Aechminidae (Primitiidae).

Kirkbyellina Kummerow, 1939, p. 30—*K. styliolata* Kummerow. Carboniferous. *Incertae sedis* (Kirkbyidae).

Leioprimitia Kummerow, 1939, p. 17—*L. punctata* Kummerow, Mississippian. Primitiidae.

Platychilina Kummerow 1939, p. 19—*P. elongata* (Krause). Devonian. Primitiidae. This is a junior homonym of *Platychilina* Koken, 1892.

Sinusella Lutkevitch, 1939, p. 195—*S. ignota* Lutkevitch. Permian. Kirkbyidae.

Vertexia Lutkevitch, mentioned in Lutkevitch, 1939, p. 192.

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ERRATA

Page 757. Footnote 2: For Schenck, read Schenk.
Age of *Bolbiprimitia* should read Upper Silurian.
Cavellinella should be in boldface type.

Page 758. Age of *Cooperatia* should read Devonian.
Insert "1941" after *Eustephanus* Swartz and Swain.

Page 759. The age of *Janetina* should read Devonian.
Age of *Kellettina* should read Lower Permian.

Page 760. For genotype of *Saccelatia*, read *Aparchites arrectus* Ulrich instead of *A. erectus* Ulrich.
For genotype of *Strepulites*, read *S. mooki* Coryell and Malkin instead of *S. mocki* Coryell and Malkin.

JOURNAL OF PALEONTOLOGY, VOL. 18, NO. 2, PP. 220–221, MARCH 1944

REVIEWS

THE BULLETIN OF ZOOLOGICAL NOMENCLATURE, vol. 1, pt. 1, pp. i–xxvi, May 21, 1943, edited by Francis Hemming, Secretary to the International Commission. (Sold at the Publications Office of the Commission.) 41 Queen's Gate, London, S. W. 7. Price, nine shillings.

In March of this year, the reviewer received a letter from Captain Francis Hemming calling attention to the publication here cited. He said in his letter that it was decided to restart the work of the International Commission on Zoological Nomenclature in two limited ways: (1) the issuing of Opinions on matters on which agreement had been reached in the Commission prior to the outbreak of war but on which Opinions have not been issued; and (2) the dissemination of information in the zoological profession in regard to proposals submitted to the Commission for decision. The latter will be done by the publication of such proposals in the *Bulletin of Zoological Nomenclature*, which has been specially established for the purpose. Even the limited activities just mentioned are difficult to maintain and it is to be desired that the Commission should receive the support of taxonomists in those countries with which postal communications are still open. The most practical way of giving such support is by the purchase of the Opinions and by subscribing to the *Bulletin*.

The first part of the *Bulletin* contains a paper by Karl Jordan, President of the International Commission, on "Decision to establish the *Bulletin of Zoological Nomenclature*." The second paper is on "The functions and powers of the International Commission on Zoological Nomenclature" by Captain Hemming. This article will be read by all paleontologists with interest.

This paper is followed by "Instructions to Authors." Taxonomists are invited to cooperate with the Commission by complying strictly with instructions when submitting proposals for consideration. The instructions are definite and clear. The proposals may then be sent to the Secretary, British Museum (Natural History), Cromwell Road, London, S. W. 7, England.

HUBERT G. SCHENCK

STRATIGRAPHY OF THE EASTERN AND CENTRAL UNITED STATES, by Charles Schuchert, 1113 pp., John Wiley and Sons, 1943. $15.00.

This book is stated to be volume two of Schuchert's "Historical Geology of North America", of which Historical Geology of the Antillean-Caribbean Region (1935) is volume one. A third volume to cover New England, eastern Canada and the arctic islands was planned.

The present volume is concerned with the stratigraphy of 30 states, which are grouped as follows: I, The New York Standard; II, States Athwart the Appalachian Geosyncline; III, Atlantic Coastal Plain (the Gulf Coastal Plain was included in the Antillean-Caribbean volume); IV, States Athwart the Cincinnati Anticline; V, States Around the Ozark Dome; VI, States of the Upper Mississippi Valley; VII, Eastern Plains States; and VIII, States to the North and West of the Borderland Llanoria. A general discussion initiates each section and each subordinate state chapter. An introductory chapter of ten pages discusses the aims of stratigraphic geology, comments upon the multiplicity of stratigraphic names, and considers the problems of dual rock and time classifications.

The main part of the book seems to be a compilation of notes, abstracts, quotations, faunal lists, and bibliographic references begun by the author in 1904. The subject matter of each of the above sections is presented state by state in stratigraphic order under such headings as "Lower Devonian (Helderbergian)—Northwest." Following the name of each formation considered is a reference to its introduction or indication of the type state, general lithologic character, thickness, and commonly a selected faunal list and additional references. Abstracts of other data and discussion by the author are sometimes included. Information relative to stratigraphic breaks is presented in a somewhat similar manner and many structures are mentioned or discussed.

There seem to be few references later than 1938 and the most recent noted are dated 1940. These consist of author's name and date only and the reader is referred to the

published bibliographies of the United States Geological Survey for other details. The volume contains no bibliography.

Illustrations consist of portraits of famous geologists and many maps, sections, and correlation tables mostly adapted from publications by others.

The emphasis of the book is predominantly Paleozoic. The pre-Cambrian is little more than mentioned, and the post-Paleozoic is accorded only one-fifth of the space devoted to the Paleozoic formations. Moreover, in accordance with Schuchert's interests, twice as many pages are awarded to the Ordovician, Silurian and Devonian systems as are given to the Mississippian, Pennsylvanian and Permian.

Many of the general discussions are good examples of Schuchert's masterful style to which geologists have been accustomed for many years but others contain inconsequential matter and some patently unsound interpretations. The treatment of materials is of variable quality and importance, and some parts seem to follow hastily written and unrevised notes. For example, some stratigraphic problems are discussed at length while others of equal importance are not mentioned; some data of historical interest are presented but on the whole the history of development of modern American stratigraphy is neglected; a consideration of the subsurface stratigraphy of Florida occupies eight pages whereas subsurface geology is almost totally ignored throughout the remainder of the volume.

My impressions of the book are largely based upon those portions dealing with the upper Paleozoic formations of the Mississippi Valley states with which I am personally familiar. In fairness to the author it should be stated that he was probably less well acquainted with the formations of this area than with those of most others. Nevertheless many errors, mostly trivial but some of considerable importance, have come to my notice. These indicate a lack of discriminate checking, and suggest that the data presented must be used with caution. Some quotations, interpretations, and statements of fact were taken from older and now outdated literature and some of the more important and more recent references are not cited. Similarly some stratigraphic names long obsolete and of little significance are presented while other names in good standing and current use are inexplicably absent. Finally, somewhat curious ideas regarding regional structure seem to find expression in such names as Ohio basin, Indiana basin and Illinois-Missouri coal basin.

My greatest criticism, however, concerns the organization within the state chapters. By attempting to present all of the stratigraphic data in chronological order, stratigraphic continuity is almost lost. There is no information as to what beds occur above and below many formations and in spite of nearly 100 correlation charts the reader will find it impossible to correlate many of them. Either beds of similar age should have been traced throughout the state and their relations explained, or the superimposed sequences of location sections considered one by one and then correlated. Geologists without knowledge of local sections are likely to find much that is confusing, particularly because information concerning the distribution of formations is inadequate.

The faunal lists, which in the aggregate make up a large part of the volume, have, I think, been overdone. They are not entirely trustworthy and most geologists will experience difficulty in separating the wheat from the chaff. Paleontological data would have been much more useful if they had been strictly limited to the listing of known guide fossils.

The stratigraphy of the eastern and central United States is a subject of such magnitude that it is too much to expect that any single man could handle it satisfactorily in all its phases. Although Schuchert's book does not attain the goal that he seems to have set for it, still it will be useful to experienced stratigraphers. It is in no sense historical geology, but it will serve as a source book for the historical geologist and will probably find its greatest usefulness as a supplement to Wilmarth's lexicon. Judging by the length of the index nearly 4000 named stratigraphic entities receive consideration.

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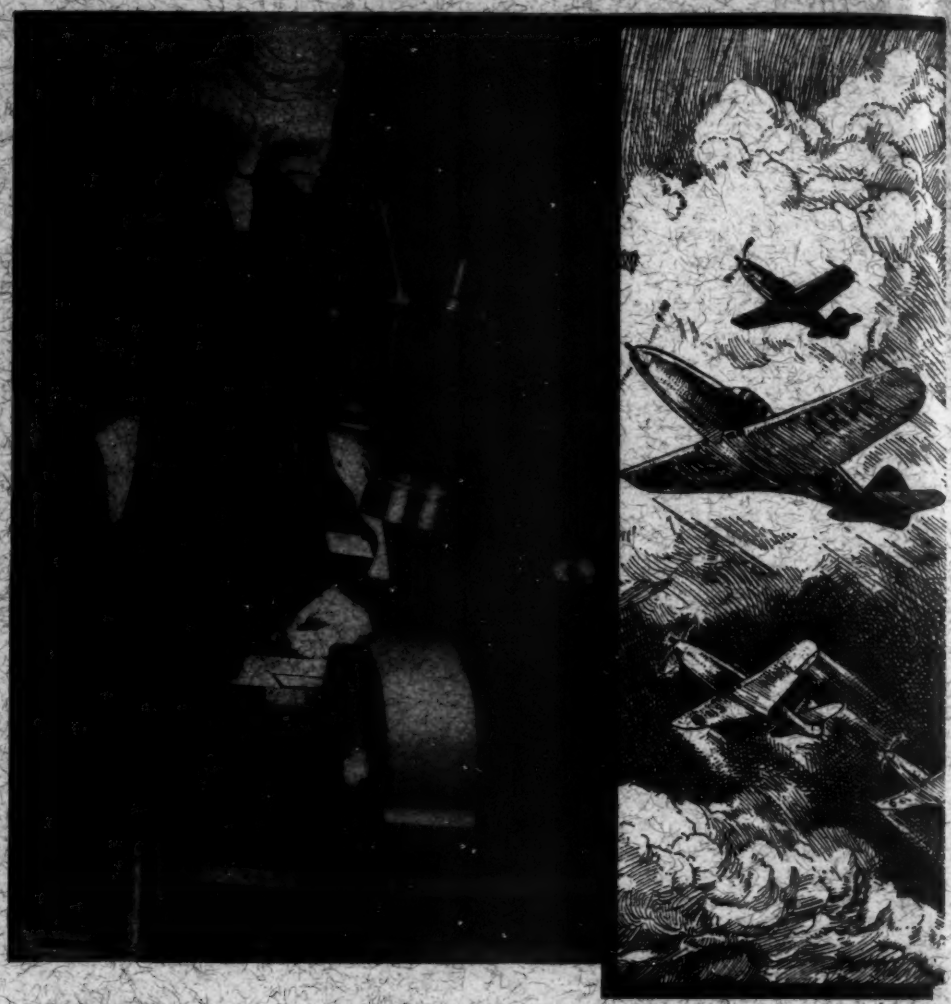

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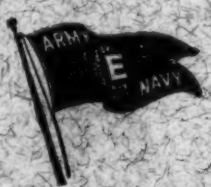

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